

Issued June 10, 1912.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE STATE OF WASHINGTON, M. E. HAY, GOVERNOR;
HENRY LANDES, STATE GEOLOGIST.

RECONNOISSANCE SOIL SURVEY OF THE
WESTERN PART OF THE PUGET
SOUND BASIN, WASHINGTON.

BY A. W. MANGUM AND PARTY.

MACY H. LAPHAM, INSPECTOR IN CHARGE.

[Advance Sheets—Field Operations of the Bureau of Soils, 1910.]



WASHINGTON:
GOVERNMENT PRINTING OFFICE,
1912

BUREAU OF SOILS.

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SOIL SURVEY.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,

Washington, D. C., September 19, 1911.

SIR: In continuation of the soil survey work in the State of Washington a reconnaissance survey was made of the western part of the Puget Sound region during 1910. The work was carried on in co-operation with the Washington Geological Survey. This work was in charge of A. W. Mangum, assisted by H. L. Westover and A. E. Kocher, of this bureau, and by the State officials, H. K. Benson and O. U. Strumme. Besides his work in the field, Mr. Benson has contributed two chapters in the report, one on irrigation in western Washington, the other on the chemical analyses of the various soils encountered. A valuable chapter treating of the climatic conditions existing in the area surveyed was also contributed by Mr. E. J. Saunders, of the University of Washington.

As a result of the assistance afforded the bureau by the State of Washington, it has been found practicable to include with this report, in addition to the usual soil map, a map showing the relation of the soils to the present character of occupation; that is, to condition of forestation and agricultural development. It is believed that this land-classification map will prove of special value to those seeking locations in this comparatively undeveloped but rapidly developing section of the country.

I recommend that the report and maps covering this work be published as advance sheets of Field Operations of the Bureau of Soils for 1910, as provided by law.

Very respectfully,

MILTON WHITNEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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RECONNOISSANCE SOIL SURVEY OF THE WESTERN PART OF THE PUGET SOUND BASIN, WASHINGTON.

By A. W. MANGUM and PARTY.

INTRODUCTION.

The area surveyed comprises a total of 4,288 square miles, or 2,744,320 acres. It includes all of San Juan, Island, Kitsap, and Thurston, and parts of Chehalis, Jefferson, Clallam, Mason, and Pierce Counties.

The areas which were omitted in the counties partly surveyed consist mainly of National Forests or of rough mountainous sections that have not yet been "logged off." The greater part of the land in these districts is of little agricultural value.

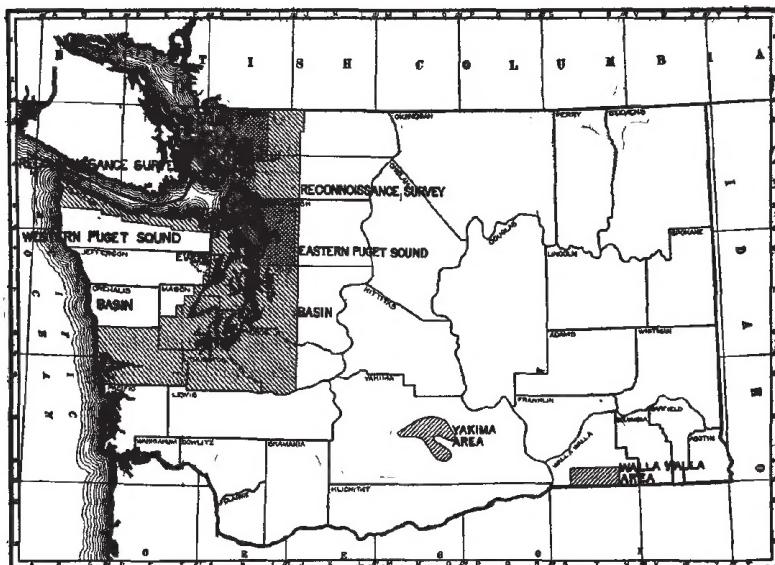


FIG. 1.—Sketch map showing area covered by the survey of the western part of the Puget Sound Basin, Washington.

Base maps.—The base maps used in this survey consist of the best available county maps, compiled mainly from the township plats of the original Government survey and from surveys made by the various counties. These maps, however, owing to errors in the original surveys, have been found to be very inaccurate in many localities, both as regards roads and streams and as regards township and section lines. Many of these errors have been corrected by the parties in the field by retraversing the roads or getting reliable data from the various county surveyors, but it was impossible in a survey of this kind to correct all errors.

Soil and land classification maps.—Two maps of the entire area have been constructed: (1) A general soil map and (2) a land-classification map. The soil map represents a reconnaissance of the soils of the various counties within the area and shows the location of the principal soil types. In some of the rougher mountainous districts, where the land is of little or no agricultural value, and in the larger areas, which are still covered by a dense growth of timber, it was impracticable to attempt to go into the detail necessary to show small isolated areas of soils. In the sections of the area which are adapted to agriculture the soils have been mapped in considerable detail.

A considerable proportion of the land-classification map was constructed from data obtained from the county assessors. The map of the districts for which no reliable data could be obtained was constructed by the parties in the field and wherever possible the data obtained from the counties were revised and brought up to date.

This land-classification map shows approximately the location and extent of the areas of five principal classes of land: (1) Cultivated lands; (2) logged off, but undeveloped land; (3) woodlands or areas covered by a nonuniform or inferior growth of timber, classed by timber cruisers as unsuitable for lumber; (4) areas covered by the original forest growth of valuable timber; and (5) treeless or very sparsely timbered gravelly prairies.

The first class represents land from which crops are derived. It is generally partly cleared of stumps and the improvements necessary for farming purposes have been made. The second class represents land from which the timber has been removed either through lumbering or by forest fires. It includes, also, areas where the timber has been thinned out by fire, so as to leave only a scattering growth, and those burned-over areas that are beginning to be covered by a young second growth. The third class represents land supporting a tree growth of nonuniform or inferior character, areas supporting only a sparse and scattering timber growth, and areas of small timber, classed as unfit for use in the lumber mills. The forest growth on land of this class is not, as a whole, nonmerchantable, as a large amount of the smaller growth is utilized for piling and ties or is exported for use in mining regions. The fourth class represents the dense original forest growth, containing a large amount of first-class merchantable timber. The fifth class includes prairie regions which are either treeless or support only a very sparse and stunted tree growth.

The lands of the area have been further separated into eight classes representing different agricultural and economic values. These differences are shown on the land-classification map by means of hachures. This classification is based principally on the texture, topography,

natural drainage, erosion, and general characteristics of the soils and gives in a general way the relative agricultural value of the land in every part of the area surveyed, with the exception of the areas embraced by the larger forest tracts. Under this system of grouping several types of soil often fall into the same general class. This does not necessarily mean that these types are equally productive, but that they are adapted to the same general type of agriculture.

Class I represents land adapted to general farming and justifying immediate agricultural development. Class II includes lands which are capable of being developed agriculturally and are adapted to intensive farming, fruit growing, and pasturage. Class III includes areas where the soil and moisture conditions are well adapted to farming, but where, owing to the steep topography and to the fact that the soil erodes rapidly, the land is better adapted to sowed crops than to those requiring constant cultivation. Class IV represents lands which can be utilized for orchards and pastures, but are not well adapted to farming. Class V includes mixed lands or areas where small tracts of agricultural land are scattered throughout more extensive areas of nonagricultural land. Class VI comprises non-agricultural lands, suitable for reforestation only. Class VII represents sparsely timbered, gravelly prairies. Class VIII includes areas of virgin forests, unclassified.

The first class includes such types of soil as those occupying the alluvial valleys and the broad, shallow glacial basins, where the soils are productive and where large tracts can be cleared and put under cultivation at a comparatively small cost. It also includes many of the upland silty or fine sandy loam soils, which have a level topography and a heavy or very compact subsoil, enabling them to conserve a sufficient amount of moisture for the growing of general farm crops.

The second class embraces the lighter-textured glacial upland soils. The open, porous character of the subsoil causes drainage to be excessive. The cost of clearing large areas of these lands is so great and the moisture conditions during the growing season are so unfavorable that only the intensive cultivation of small areas has proved profitable.

The third includes the more rolling and hilly section of some of the residual soils, such as the Hoquiam clay loam and Melbourne silty clay loam. In these hilly sections the steep topography causes the soil to erode or slide during the rainy season. When cleared of the natural forest growth the erosion of the land in this class is so severe that both the soil and subsoil are rapidly washed down from the steeper slopes, leaving the underlying rocks exposed on the surface.

The fourth class includes many of the gravelly or stony gravelly soils of the glaciated uplands. The gravelly stony texture of these

soils makes thorough cultivation of the land very difficult and in many cases almost impossible. The subsoils are too coarse to retain sufficient moisture for the profitable production of general farm crops.

The fifth class includes areas where small tracts of level or gently rolling land, comparatively free from stones and well adapted to agriculture, occur at frequent intervals throughout larger areas that are so stony or have such a rough topography that they are of no agricultural value.

The sixth class embraces nonagricultural land. This land consists of rough, hilly, or mountainous districts, where the topography is so rough and broken that successful cultivation of the land is impossible. It also includes areas where stones and boulders in both the soil and subsoil make the land unfit for agricultural use.

The seventh class includes the broad, gravelly prairies of glacial outwash, so excessively drained that they are at present generally of little agricultural value.

The eighth class includes the extensive areas which are still covered by the dense original forest growth. These lands are at present valued mainly for the timber they support.

Where small tracts of one class occur in larger areas of some other class it was found impracticable to attempt their separation, and they are included in the class which represented 80 per cent or more of the land.

DESCRIPTION OF THE AREA.

The area surveyed may be roughly divided into three general regions: (1) The San Juan Island region, possessing largely a strongly glaciated rock topography and limited practically to San Juan County; (2) the region wholly or for the most part characterized by glacial deposits and included in Island, Kitsap, and Thurston Counties and in the portions covered by the survey in Clallam, Jefferson, Mason, and Pierce; (3) the unglaciated or residual district surveyed, including a part of Chehalis and Thurston Counties.

FIRST OR GLACIATED ROCKY REGION.

San Juan County consists of a group of small islands situated in Puget Sound, between Vancouver Island and the islands included with the adjacent part of the mainland in Skagit County. San Juan County has an area of 187 square miles, the greater part of the land suitable for agricultural purposes being found on the three larger islands, San Juan, Orcas, and Lopez (Pl. I, fig. 1).

The topography of San Juan County, as a whole, is rough and hilly, the hills rising abruptly along the coast, often forming precipitous bluffs or rocky cliffs with little or no areas of beach between

the water at high tide and the base of the cliffs (Pl. I, fig. 2). The greater proportion of the upland on both San Juan and Orcas Islands is rough and broken, with extensive areas of rock outcrop along the steeper slopes. Small, gently rolling areas or broad, shallow valleys and basins occur at frequent intervals between the rocky hills and ridges, while small plateaus or bench lands, which could be utilized for agricultural purposes, are found scattered throughout the rough and hilly sections.

The surface of the small basins or valleys is almost level. These depressions vary from small isolated basins containing only a few acres to broad valleys of more than 2 square miles extent. The most mountainous sections of the islands are found in the northeastern part of Orcas Island, where Mount Constitution, within less than a mile from the coast, rises to an elevation of 2,400 feet, and in the southwestern part of San Juan Island. Here is found Mount Dallas, with an altitude of more than 1,000 feet. The topography of Lopez Island is not so rough as that of the other large islands of the group, and, with the exception of the rocky hills at the southern end, the principal topographic features consist of gently rolling uplands, with small, level valleys or basins intervening. The greater proportion of Waldron Island also has a gently rolling topography, but the other smaller islands of the group consist mainly of rocky hills and ridges, with only a small percentage of level agricultural land. Much of the choicest timber has been cut in San Juan County, but there are still considerable areas of valuable fir and cedar on several of the islands.

Only a very small proportion of the uplands in San Juan County has been cleared, the great part being either "logged-off" land or covered by the original forest. The farms are almost entirely confined to the shallow basins or small prairies. The principal towns in San Juan County are Friday Harbor and Roche Harbor on San Juan Island and Eastsound on Orcas Island. There are many other towns of 50 to 200 inhabitants on the various islands of the San Juan group. These towns are important shipping points for the surrounding country. There are a number of smaller towns which are of considerable importance. Almost every port has one or more daily boats running between the islands and the larger towns on the mainland. These furnish ample transportation facilities for marketing the products of this section of the area.

SECOND REGION OR REGION PRIMARILY OF GLACIAL DEPOSITS.

The glaciated districts of the mainland included in this survey lie on the western side of Puget Sound, with the exception of that part of the area included in Thurston County which lies directly south

of the Sound. In Clallam County only a narrow belt was surveyed, which lies between the Olympic National Forest on the south and the Strait of Juan de Fuca on the north. The eastern end of this belt joins that of the area surveyed in Jefferson County. This comprises the townships lying east of the mountains and national forest reserve. Kitsap County lies southeast of Jefferson and is separated from it by a narrow arm of Puget Sound. The survey also includes the two small peninsulas of Pierce County which lie directly south of Kitsap County. The townships of Mason County lying south and east of the national forest and all of Thurston County which is located at the southern extremity of Puget Sound are also included in this general division.

Island County consists principally of two large islands, Whidbey and Camano, situated in Puget Sound, west and northwest of Snohomish County. These islands have a total area of 233 square miles. Besides the two main islands, the county includes the very small islands of Deception and Ures, which consist almost wholly of rock outcrop and afford little or no opportunity for agriculture.

The islands consist of gently rolling upland, of more or less extensive, level to gently rolling upland plateaus, of broad depressions representing basins of glacial lakes, and of small level areas locally known as "prairies."

The elevation of the rolling upland districts varies from 50 to 150 feet, with an occasional hill rising to a height of about 300 feet. The hills and ridges are rounded and the slopes are seldom steep enough to interfere with cultivation. The upland plateaus have the general appearance of being almost level. They occur as benches in the rolling upland section or as flat areas, capping the summits of some of the rounded hills. They vary from a few acres to more than 1 square mile in extent. The old lake basins are shallow and are usually of limited extent.

The topography of the small "prairies" is comparatively level. The larger one, known as Ebey's Prairie, has the general appearance of a broad basin, and the large amount of organic matter in the surface soil indicates that it was at one time an area of poor drainage. The only streams on the islands are small intermittent drains which serve as an outlet for the excess water during the rainy season, but the rolling topography insures good natural drainage to the land in every part of the county, with the exception of a few small areas occupying the lower basins or depressions. These receive the drainage waters from the surrounding uplands.

Topography and drainage of Clallam and Jefferson Counties.—The topography of the greater part of the area surveyed in Clallam and Jefferson Counties is very rolling. Near Clallam Bay the foot-hills of the Olympic Mountains extend almost to the coast, and the

surface here is rough and broken. There is a broad plateau or bench, averaging from 1 to 3 miles in width, which extends along the coast from near Gettysburg eastward almost to the Jefferson County line. This area is comparatively level or gently rolling, though it is intersected by several deep gorges cut by swift mountain streams. Back of this plateau the uplands are very rolling and the topography rapidly becomes more hilly and broken as the southern boundary is approached.

The area surveyed in Clallam County is traversed by many small rivers and streams rising in the mountains to the south and flowing northward into the Strait of Juan de Fuca. Of these the Elwha, Dungeness, and Clallam Rivers are most important.

With the exception of a few small plateaus and valleys the area in Jefferson County is rolling to hilly. The western boundary of the survey crosses the foothills of the Olympic Mountains, and in this locality the county is rough and mountainous. The principal streams in this part of the area are Big and Little Quilcene, Dusewallips, and Duckabush Rivers.

Topography and drainage of Kitsap and Pierce Counties.—The coast line of both Kitsap County and the small peninsulas of Pierce County is very irregular, numerous small arms of Puget Sound extending inland between the steep bluffs of the coast. The greater part of the area embraced by these counties consists of gently rolling uplands, but the hills are seldom steep, and small level plateaus and shallow basins occur in many localities.

Topography and drainage of Mason County.—In Mason County the surface of the country bordering the coast and on either side of Hood Canal is quite rolling. Back from the coast it becomes more level, and a large proportion of the west-central part of the county has the appearance of a gently rolling upland plateau. A range of the "Black Hills" extends in an east and west direction across the southern part of the county, giving the region southwest of Shelton a very rough and hilly topography. A long narrow arm of Puget Sound, known as Hood Canal, enters the county from the north and extends inland for a distance of about 20 miles. Between the western boundary of the area and this narrow inlet the surface of the county is very rough and broken, the region forming a part of the foothills of the Olympic Mountains.

The principal streams within the townships surveyed are the Hamahama, Lilliwaup, and Skokomish Rivers, which rise in the mountains to the northwest and empty into Hood Canal, and the Satsop River and its main tributaries, which traverse the southwestern part of the county.

Topography and drainage of Thurston County.—The principal topographic features of Thurston County consist of (1) the broad,

comparatively level prairie region, which extends in a more or less unbroken body across the county from northeast to southwest; (2) the mountainous district, which is located in the extreme southeastern corner of the county; (3) the range of hills, known as the "Black Hills," extending along the boundary between Thurston and Chehalis Counties; (4) the gently rolling glacial uplands, which embrace the greater proportion of the northern townships; and (5) the rolling to hilly area extending along the south boundary. A large proportion of the central part of Thurston County is drained by the Deschutes River, which rises in the mountainous districts of the southeastern corner and flows in a general northwesterly course, emptying into Puget Sound near Olympia. The western townships are drained by the Black River. The Nisqually River, which forms the boundary between Thurston and Pierce Counties, is the largest stream in this section of the area and serves as an outlet for the drainage waters of the extreme western townships. The southern part of Thurston County is drained principally by Skookum Chuck and Chehalis Rivers.

THIRD OR RESIDUAL REGION.

The district surveyed in the residual belt, south of the glaciated region, embraces parts of Chehalis and Thurston Counties. Chehalis is situated west of Mason and Thurston Counties and is bounded on the west by Grays Harbor and the Pacific Ocean. The area surveyed in Thurston County falling within this division of the area lies in the southern part of the county. There are three main physiographic divisions in Chehalis County—(1) the rolling to hilly uplands; (2) the broad alluvial valley of the Chehalis River; and (3) the broad bench or table land lying west of the Humptulips River. The surface of the uplands on both sides of the Chehalis Valley is rolling to hilly. The hills are rounded, with small shallow valleys intervening, but the slopes are often very steep and when the land is cleared of the original timber growth the soil erodes very rapidly. The land occupying the valley of the Chehalis River is almost level. This valley crosses the county in a general westerly direction and has an average width of about 2 miles. The extensive bench or table land lying between the Humptulips River and the coast has the general appearance of being almost level, but low, rounded elevations and small shallow depressions occur at intervals throughout the area, giving it as a whole a gently rolling topography. The greater part of Chehalis County is drained by the Chehalis River and its tributaries, the most important of which are the Satsop, Wynooche, Wishkah, and Hoquiam Rivers. The northwestern townships surveyed are drained by the Humptulips, Copalis, and Moclips

Rivers, the first flowing into Grays Harbor and the last two directly into the Pacific Ocean. A small area along the southern boundary line is drained by the North River, which traverses this part of the area and finally empties into Willapa Harbor.

SETTLEMENT.

Settlement has progressed more rapidly in Thurston County than in any other sections of the area. In this county as well as in Chehalis County, the valleys of the larger rivers, such as the Chehalis and Skookum Chuck and their larger tributaries, are comparatively thickly settled, while the rolling uplands, except in the immediate vicinity of the larger towns, are only sparsely settled. Large areas in the rough mountainous districts are almost uninhabited. There are many small towns in both Kitsap and the parts of Pierce County surveyed which have grown up as a result of lumbering operations. Most of these settlements are located along the coast; the greater part of the rolling uplands is very sparsely settled.

In Jefferson, Clallam, and Mason counties the settled areas lie chiefly in the vicinity of the larger towns and in the large alluvial valleys and glacial basins. The most thickly settled district in these counties is near Sequim and Dungeness, in Clallam County, where irrigation is practiced and a considerable area has been developed agriculturally. Back from the coast the greater part of the rolling uplands is still covered by the original forests or is in the undeveloped state known as "logged-off" land.

Towns.—The chief towns within the area surveyed consist of Olympia, the capital of the State, located in Thurston County, the population, census of 1910, being 6,996; Aberdeen and Hoquiam, located on Grays Harbor, in Chehalis County, having populations of 13,660 and 8,171 respectively; Shelton, located on Oakland Bay, in Mason County, with about 1,163 inhabitants; Port Orchard and Bremerton, in Kitsap County, Port Townsend in Jefferson, and Port Angeles in Clallam Counties.

TRANSPORTATION.

Two of the counties within the area are traversed by the main lines or branches of two or more transcontinental railroads. The Northern Pacific, Union Pacific, and Great Northern traverse Thurston County, using jointly the main line between Seattle and Portland. From Centralia, Lewis County, a branch of the Northern Pacific extends northward, connecting with the Seattle & Grays Harbor branch of this road, at Gate, Thurston County. The latter line crosses Thurston and Chehalis Counties, following the north side of the Chehalis Valley to Hoquiam on Grays Harbor and then north-

ward along the coast to Moclips. A small branch of this road extends along the southern coast of Grays Harbor, connecting Aberdeen and Ocosta.

A branch of the Chicago, Milwaukee & Puget Sound Railway crosses Thurston County in a general northeast-southwest direction. On entering Chehalis County this road follows the south side of the Chehalis Valley, terminating at Aberdeen, on Grays Harbor. The central part of Thurston County is traversed by a short line of railroad, known as the Port Townsend Southern, which connects Olympia and Tenino. A branch line of the Union Pacific, which will traverse the southern part of Chehalis, is now being constructed. There are also many small logging railroads in these counties which connect the principal towns with points in the surrounding country.

The counties of Clallam, Jefferson, Kitsap, Mason, and the small part of Pierce County included in the survey have no railroad facilities, with the exception of the small local line used mainly for logging, and a short branch of the Port Townsend Southern, which extends from Port Townsend to Quilcene. All of these counties, however, are partially surrounded by the waters of Puget Sound and small deep-water ports and harbors occur at frequent intervals along the coast, so that almost every locality within the district surveyed in these counties is within easy reach of some local port or shipping point, reached by the steamers which run regularly between the larger cities and the various points on Puget Sound. The northern part of Thurston County also has the advantage of water transportation, and Olympia is a port of considerable importance.

MARKETS.

The cities and small lumbering towns situated within the counties surveyed furnish good local markets for the products of all sections of the area. Products not sold in these local markets are shipped principally to Tacoma, Seattle, or Portland, Oreg. A considerable quantity of fruit is shipped to eastern markets and to Alaska.

CLIMATE.¹

GENERAL DISCUSSION.

The climate of the area is determined by its position on the western slope of the Pacific Coast Mountains, directly in the path of the prevailing westerly winds and the accompanying storm vortexes which move over it from the Pacific Ocean. It is thus subject to the moderate winter and summer climate characteristic of large bodies of

¹ Prepared by E. J. Saunders, of the University of Washington.



FIG. 1.—EXAMPLE OF OCCASIONAL SMALL CLEARING ON SAN JUAN ISLAND.
[Canada field peas in foreground; oats in background.]



FIG. 2.—STEAMER LANDING AT RICHARDSON, LOPEZ ISLAND, SHOWING FREQUENT
RUGGED CHARACTER OF COAST LINE OF THE ISLANDS OF THE SAN JUAN GROUP.

water, and is protected by the Cascade Mountains and the British Columbia ranges from the climatic extremes characteristic of the continental interior which would otherwise be brought to it by occasional north and east winds.

The constant but irregular changes in the weather are caused by the movement of low-pressure areas or storm vortexes across the area in an easterly direction. Toward these centers the air moves from all sides and ascends spirally. If they pass north of the section the winds are from the south, are warm, and usually cause heavy precipitation, but if to the south the winds are from the north, are cooler, and cause less precipitation. The low-pressure areas or cyclones are accompanied by high-pressure areas or anticyclones, in which the air is slowly descending and moving spirally outward. They cause clear, cold weather in the winter and warm, clear days, with cool nights, in the summer. Thus the weather conditions during any month or season will vary with the intensity, number, and position of these low-pressure and high-pressure areas which pass over the State in their journey eastward.

The topography of the area plays such an important part in determining its climatic conditions that it may be well to notice the relations of the topographic features before describing the climate in detail. The Olympic Mountains, a rugged mass, from 3,000 to 8,000 feet high, occupy the central part of the area between the Pacific Ocean on the west and Puget Sound on the east, and extend southward from the Strait of Juan de Fuca to the broad, low gap occupied by Grays Harbor and the Chehalis River. A lower range of mountains, extending southward from the Chehalis River gap to the Columbia River, separates Willapa Harbor from the southern part of the Puget Sound Basin, but is less important as a climatic barrier than the higher Olympics. The warm, moisture-laden winds from the Pacific, moving eastward under the prevailing influence of the westerlies and the storm vortexes, are forced to ascend the western slopes of these mountains, and thus cause heavy precipitation, while through the low Chehalis River gap the winds may carry the moisture into the Puget Sound Basin and deposit it in constantly decreasing amount until they begin to ascend the western slopes of the Cascade Mountains.

PRECIPITATION.

The average annual precipitation of the region (see fig. 2) shows a remarkable variation from more than 140 inches at Quinault on the west slope of the Olympics to 21 inches at Port Townsend and Coupeville in the upper Sound country and in the lee of the mountains. The forced ascent of the moisture-laden air as it moves eastward and

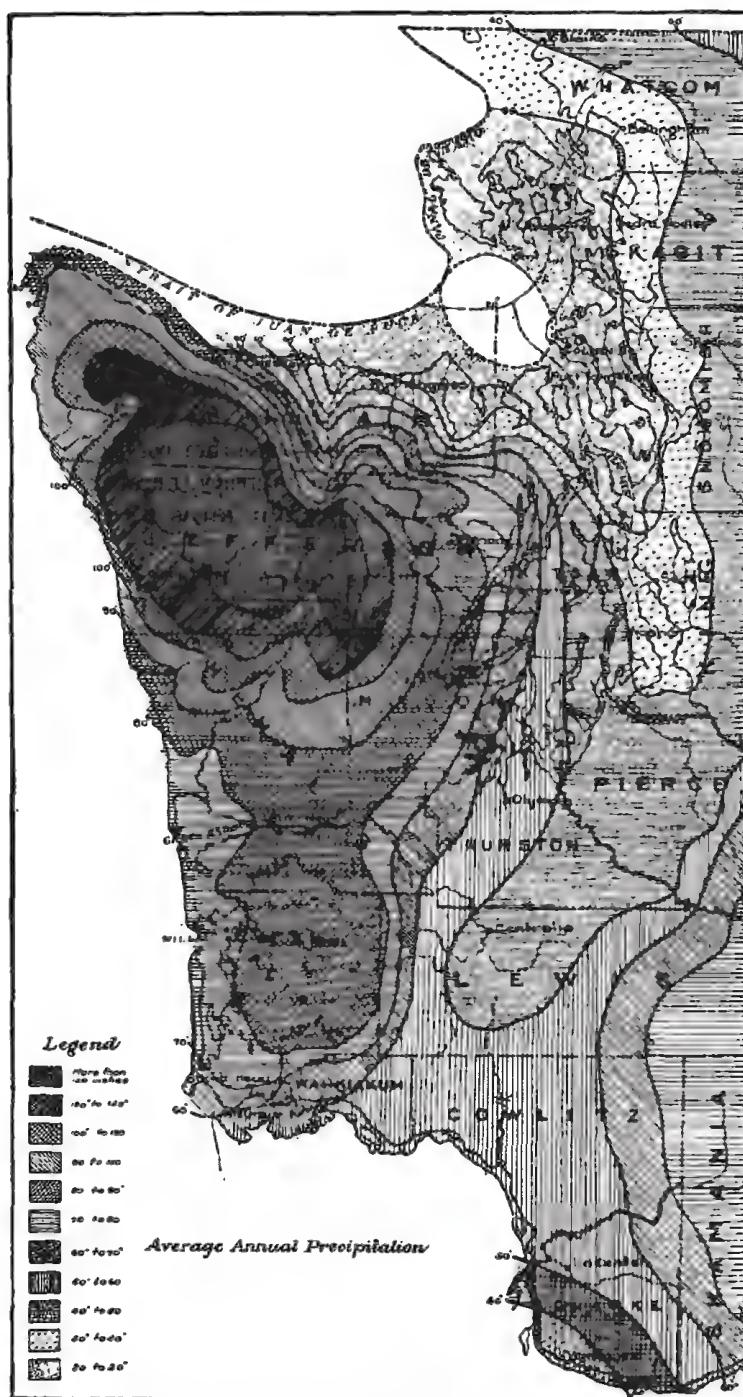


FIG. 2.—Sketch map showing average annual precipitation.

northward into the storm vortexes causes heavy precipitation on the west slope, while at Port Townsend and Coupeville a large part of the moisture has been removed from the southerly winds, and the northerly winds moving into the storm areas do not cause such heavy precipitation. The continuation of the coastal wet belt on the southern slope, and even around to the eastern slope of the Olympics, where there is 83 inches of rainfall at Union City and 75 inches at Brinnon, is explained by the forced ascent of air up the southern and eastern slopes of the mountains as it moves toward the storm centers passing over the Sound farther north. The precipitation on these slopes is not as great as on the west slope, because part of the moisture is removed from the air as it moves inland through the Grays Harbor country before it reaches the mountains. In the low, broad valley of the Chehalis River, through which the moisture-laden air passes on its way to Puget Sound, there is a more rapid decrease in the annual precipitation. At Aberdeen, near the coast, there is 86 inches, at Olympia 55 inches, at Tacoma 43 inches, and at Seattle only 35 inches per year. The mountains south of Grays Harbor show a similar effect in causing a heavier precipitation on the windward and ocean side, South Bend having 89 inches per year, while Centralia, on the leeward side, has only 35 inches per year. The absence of stations makes it impossible to give the exact figures for precipitation here or near the summit of the Olympic Mountains, but it probably increases with altitude, at least to 3,000 or 4,000 feet.

The annual snowfall (see table, p. 22) is light at all stations in the area, ranging from 3.3 inches at North Head, on Willapa Harbor, to 27.4 inches at Brinnon, on Hood Canal. The absolute annual maximum for the 10-year period was 32 inches at Tatoosh, on the coast, and 48 inches at Brinnon, on the inland side of the mountains. At the stations, which are all in low altitudes, the snow remains on the ground for only a short time and has therefore little effect upon vegetation or climate. But in the higher mountains it collects in large quantities and remains the greater part of the year, thus greatly modifying the temperature conditions and making the water supply of the streams which flow from their slopes fairly constant even during the dry summer season. If otherwise favorably situated, these streams should therefore furnish excellent water power and water supply.

The monthly distribution of rainfall at the different stations is shown in figure 3. A study of this map shows that very little rainfall occurs at any of the stations during July and August, and that June and September have a very light rainfall as compared with the winter months, except at Port Townsend and Coupeville. The

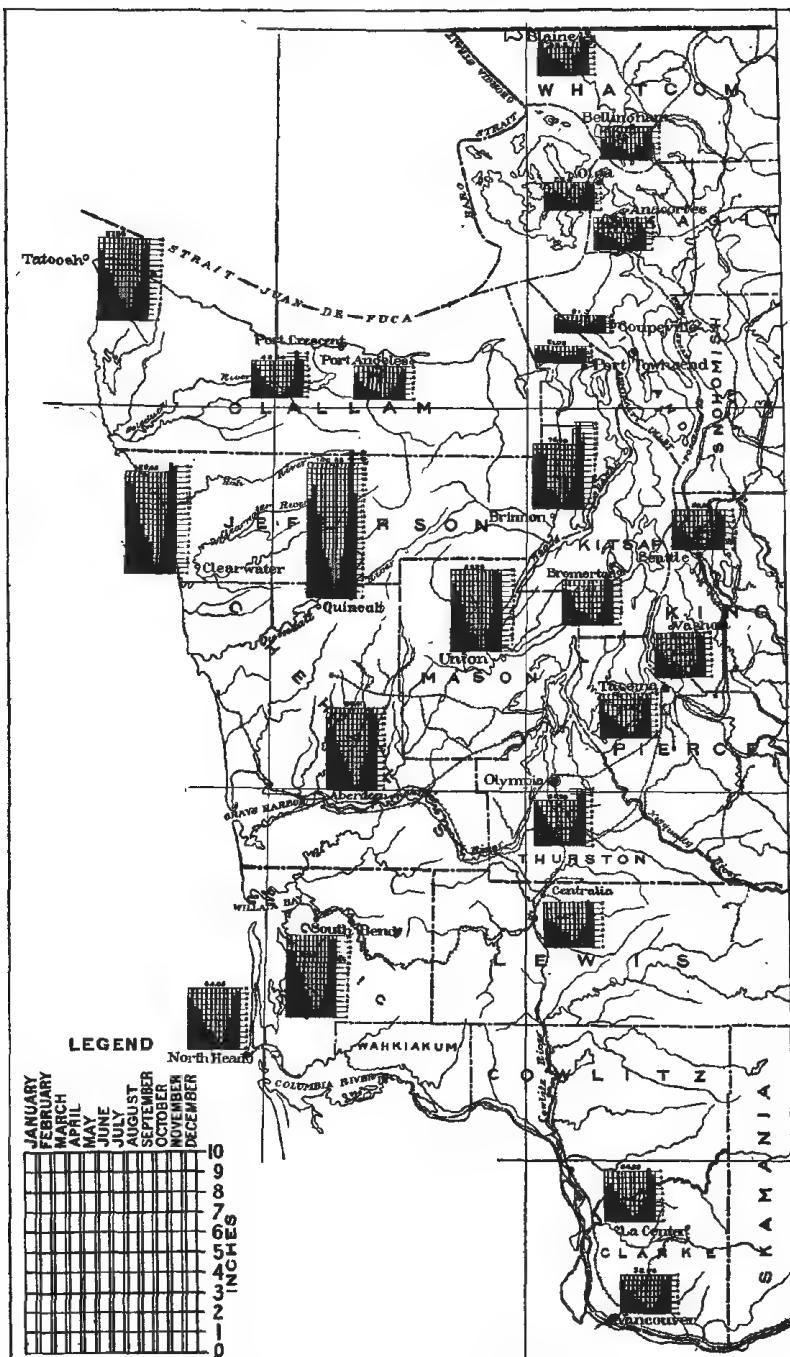


FIG. 3.—Diagram showing average monthly precipitation.

heaviest precipitation occurs during November, December, January, and February, and for many of the stations the maximum rainfall occurs in November. Taking the average for all the stations, about 85 or 90 per cent of the total precipitation occurs in the eight months, October to May, inclusive, and about 75 per cent in six months, November to April, inclusive.

The reasons for the concentration of the precipitation in the winter months are: (1) The cyclonic or storm areas passing over the section from the west are more numerous and better developed in the winter than in the summer, thus causing more frequent and heavier precipitation in the winter months; (2) during the winter the ocean is warmer than the land, and the air laden with moisture, moving from the warmer ocean, is cooled quickly as it moves inland over the cooler land mass, thus causing rapid condensation and heavy precipitation. Condensation is increased as the air is forced to ascend rapidly in passing over the mountains. During the summer, however, the ocean is cooler than the land, and the air moving from the cooler ocean to the warmer land is not cooled sufficiently to cause the heavy precipitation that occurs in the winter. This effect is emphasized by the fact that the winter winds along the coast are prevailingly from the southwest and become cooler as they blow northward, thus causing more rapid condensation, while in the summer they are prevailingly from the northwest, becoming warmer as they blow southward and inland.

The November maximum of precipitation is no doubt due to the fact that during November there are fewer prolonged cold spells, which interfere with the landward movement of moisture-laden air, than during December and January and therefore a greater number of days with heavy precipitation.

The daily variation in precipitation has not been worked out for the whole section, but observations at Seattle show that between 70 and 75 per cent of the total precipitation occurs during the night hours or between 5 p. m. and 5 a. m.

CLOUDINESS.

An important element in the climate of a section is the number of rainy, cloudy, and clear days. But the observations for cloudiness, being noninstrumental in most cases, are not as reliable as other climatic data. The following table gives for all the stations along the coast and for a few of the interior stations the annual means for the period covered by the Weather Bureau observations.

Snowfall and number of rainy, cloudy, and clear days.

Coast stations.	Snowfall in inches.	Days with more than 0.01 inch rainfall.	Cloudy days.	Partly cloudy days.	Clear days.
Aberdeen.....	15.7	175	142	101	122
Clearwater.....	13.2	200	157	65	143
North Head.....	3.3	201	197	90	78
Quiniault.....	17.0	208	125	98	142
South Bend.....	4.9	160	104	89	172
Tatoosh.....	10.5	202	226	73	66
Average.....	10.7	191	158	86	121

Interior stations.	Snowfall in inches.	Days with more than 0.01 inch rainfall.	Cloudy days.	Partly cloudy days.	Clear days.
Centralia.....	11.3	162	130	123	112
Bremerton.....	20.2	173	184	76	105
La Center.....	11.4	157	110	140	115
Olympia.....	10.0	163	152	124	82
Seattle.....	11.8	147	157	129	79
Tacoma.....	13.7	156	187	100	78
Vashon.....	9.0	159	128	77	160
Union City.....	23.1	169	153	86	128
Average.....	13.8	161	150	107	108

The stations along the coast show the greatest number of days on which a measurable quantity of rainfall occurs, and Tatoosh with 202 days has the maximum number for stations where observations have extended over 10 years. Quiniault for four years averages 208 days. Port Townsend, Coupeville, and Anacortes have the fewest rainy days, with a yearly average between 130 and 110. The average for the six coastal stations is 191 rainy days per year, while for the southern part of Puget Sound Basin, including stations named in the table, the average is 161 rainy days. Many of the days on which rain falls, however, are clear and pleasant most of the day, with only a short period of rainfall in the morning or evening.

South Bend has the greatest number of clear days, 172 a year, and Tatoosh the lowest number, 66 a year, but in this case the personal opinion of the observer has to be taken into account, and the figures given are approximate only. The coastal stations have an average of 121 clear days, while the interior stations have an average of only 108 clear days.

The average year along the coast would have 191 days with rain, 158 cloudy days, 86 partly cloudy days, and 121 clear days, while

the average year in the Sound Basin would have 161 days with rain, 150 cloudy days, 107 partly cloudy days, and 108 clear days.

At all times the air shows a high relative humidity, causing the formation of heavy fogs and dew by a slight lowering of the temperature of the air from different causes.

TEMPERATURE.

The mean annual temperatures at different stations show less than 5° variation for the section, the lowest being 47° at Port Angeles, the highest 51.5° at Bremerton. A study of these means gives such a vague idea of the real distribution of temperature conditions throughout the section and throughout the year that very little attention is given them in this report and no map made to show areas of equal temperature.

The general uniformity of temperature characteristic of marine climate is shown by the study of the annual, monthly, and daily ranges of temperatures for different parts of the section. The mean annual range, or difference between the average temperature of the coldest month and the average temperature of the warmest month, is between 14° and 20° for the coast stations and between 22° and 30° for the inland stations. The lowest annual range is 14.3° at Tatoosh, with a February mean of 41° and a July mean of 55.3°. The highest annual range is 29.3° at Vancouver, with a January mean of 37.7° and a July mean of 67°. This range is several degrees greater than the range for any other station from which records can be obtained. The average temperature for the coldest months, in most cases, January, varies from 42.1° at South Bend and 41.8° at North Head, in the southern coastal section, to 36.5° at Port Angeles and Port Crescent, along the Strait of Juan de Fuca. The average for the warmest month, July, varies from 67° at Vancouver to 56.2° at Port Crescent and 55.3° at Tatoosh.

The average of the lowest temperatures recorded at different stations varies from 24.3° at Tatoosh and 22° at North Head, on the coast, to 15° at Olympia, Bremerton, and Port Crescent, and 12° at Centralia and Vancouver. The lowest recorded temperatures occurred in 1893, -6° at La Center, -3° at Olga, -2° at Olympia, and for the coast stations 14° at Tatoosh, 11° at Clearwater, South Bend, and Aberdeen, and 6° at North Head. Such low temperatures are not at all common and temperatures below 32° occur on the average only about 20 days each year.

The average of the highest temperatures varies from 98.3° at Clearwater, Centralia, and La Center to 85° at Port Crescent and Port Townsend, and 75.7° at Tatoosh. The highest temperatures ever recorded were 105° at Aberdeen, 104° at Olympia and North Head, and 102° at Centralia. While these high temperatures are

occasionally recorded, it is only on one or two days annually that the temperature goes above 90°, and at Seattle the temperature has gone above 90° on only 20 days in the last 18 years.

The average daily range of temperature at Seattle is about 9° during the winter months and 18° during the summer months. The greatest ranges are from 25° to 30° during the summer months, while the least daily range is about 3° and occurs during the rainy days of winter. Thermograph record I (fig. 4) shows the characteristic daily changes of temperature for the latter part of July during a warm spell and during a cloudy spell. Record II (fig. 4) shows the small daily range during a rainy spell in January with southwest winds and low barometer. Record III (fig. 4) shows the daily variations during a cold wave in January with winds from the northeast and a high barometer.

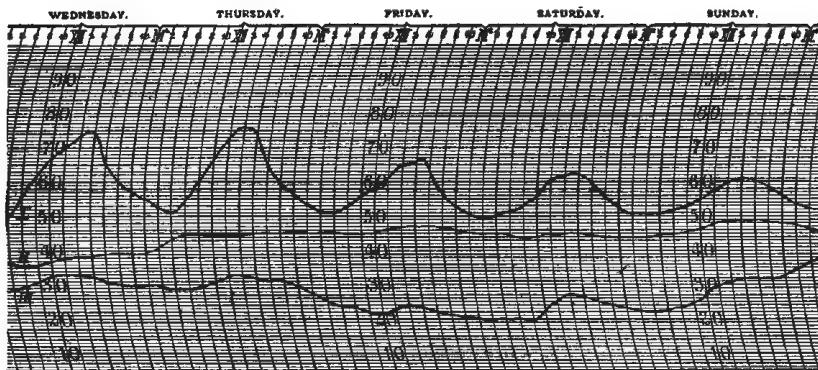


FIG. 4.—Diagram showing typical temperature curves: I, summer temperature curve, week of July 25, 1910; II, winter temperature curve, week of January 2, 1910; III, winter temperature curve, week of January 9, 1910.

The mean variability or change of mean temperature from day to day is about 3° in winter and 2.5° in summer, although occasionally the mean temperature will vary 15° or 20° between two successive days.

While this remarkable uniformity of temperature may be accounted for by the fact that the winds come from the Pacific Ocean, which is warmer in winter and cooler in summer than the adjacent land areas and thus causes higher winter temperatures and lower summer temperatures than would otherwise occur, we must take into account also the effect of low pressure or storm areas. The usual winter track of these storm-producing areas is so far to the northward that southerly and southwesterly winds prevail and these being warmer cause higher temperatures. Then, too, the condensation of the moisture carried by these moisture-laden winds causes an appreciable rise in temperature and thus increases the warming effect of the southerly

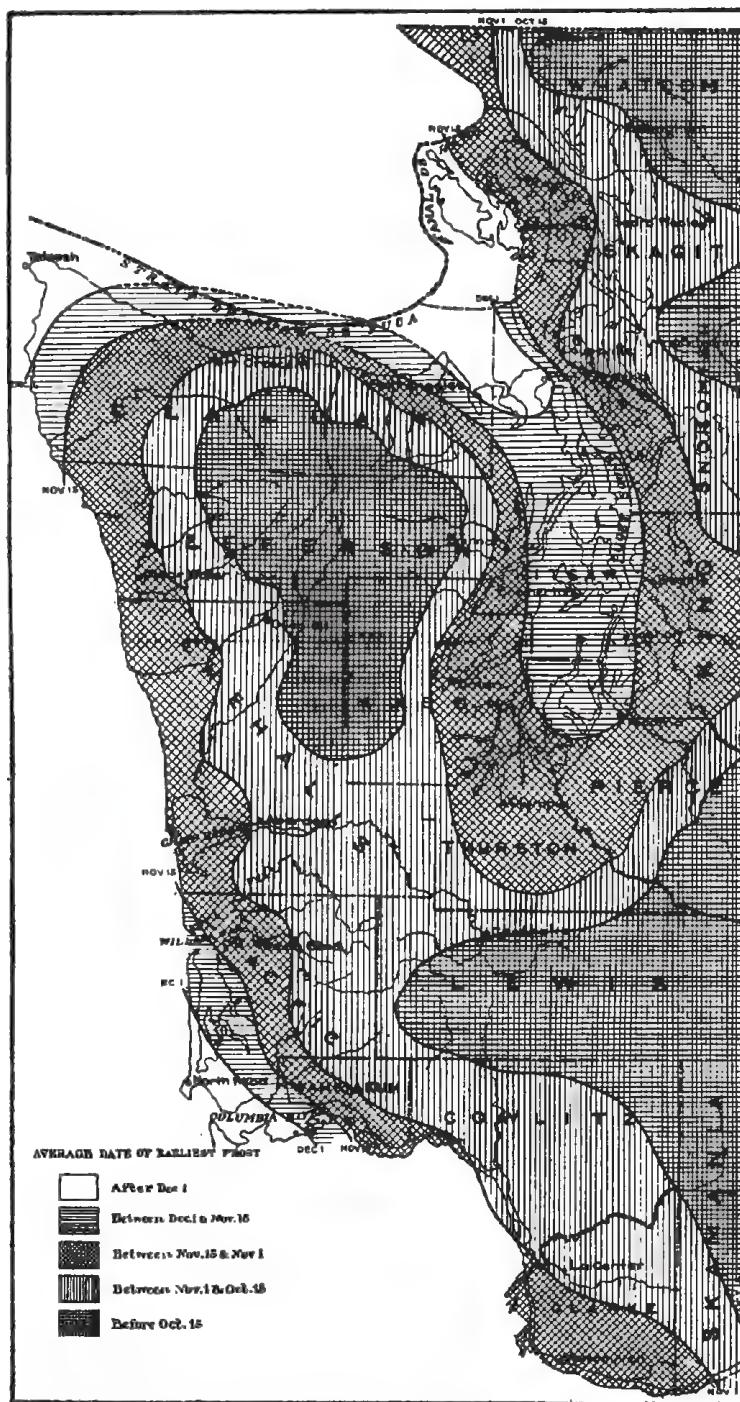
oceanic winds. As a result of these conditions the rainy days which accompany the passage of a cyclonic area to the north of the section, and of which there are a considerable number during the winter months, are particularly mild and enjoyable. The temperature under these conditions is shown by the thermograph record II (fig. 4). When the storm center is so far south that northerly winds prevail the weather is generally fair, and if a high pressure or anticyclonic area extends over British Columbia we have cold northerly or north-easterly winds and a cold spell usually results with snow flurries or clear frosty weather. The temperature under these conditions is shown in thermograph record III (fig. 4). These cold spells are infrequent, while the warm spells are of frequent occurrence during the winter and thus the mild winters are interrupted by only one or two colder spells, which are generally of short duration.

During the summer very few well-developed storm areas move over the section, and the winds coming from the Pacific, and generally from a northerly direction, moving toward the continental low-pressure area to the southeast, cause low temperatures, with considerable cloudy weather but little precipitation. At this time dry weather prevails, and the nights and forenoons are cool, while the afternoons are pleasantly warm. When a high-pressure area extends over British Columbia and eastern Washington we have clear, warm days, but still have pleasant, cool nights. Both of these conditions are shown in thermograph record I (fig. 4), the first part of which shows a warm spell, the last two days showing the common type of summer temperature changes.

KILLING FROSTS.

From the dates on which the earliest killing frosts in the fall and the latest killing frosts in the spring have occurred at the different stations the average date in each case has been worked out and the results plotted in figures 5 and 6. Although there is great irregularity in the dates on the different years, these maps indicate approximately for the different belts the dates between which the earliest and latest frosts may be expected. As they usually occur under the influence of an extensive high-pressure area, the date in any particular year is apt to be the same for a number of stations. The marine influence and the influence of altitude are well shown on the map, also the influence of river valleys, which either allow the cold air to drain away toward lower levels, or, if wide and flat, allow the colder air to collect in them from the surrounding slopes, and thus are subjected to earlier and later frosts than the adjacent uplands.

The earlier frosts in the fall occur at stations farthest north or farthest from the marine influence. The earliest average date is for Centralia October 14 and Port Crescent October 22, and the latest



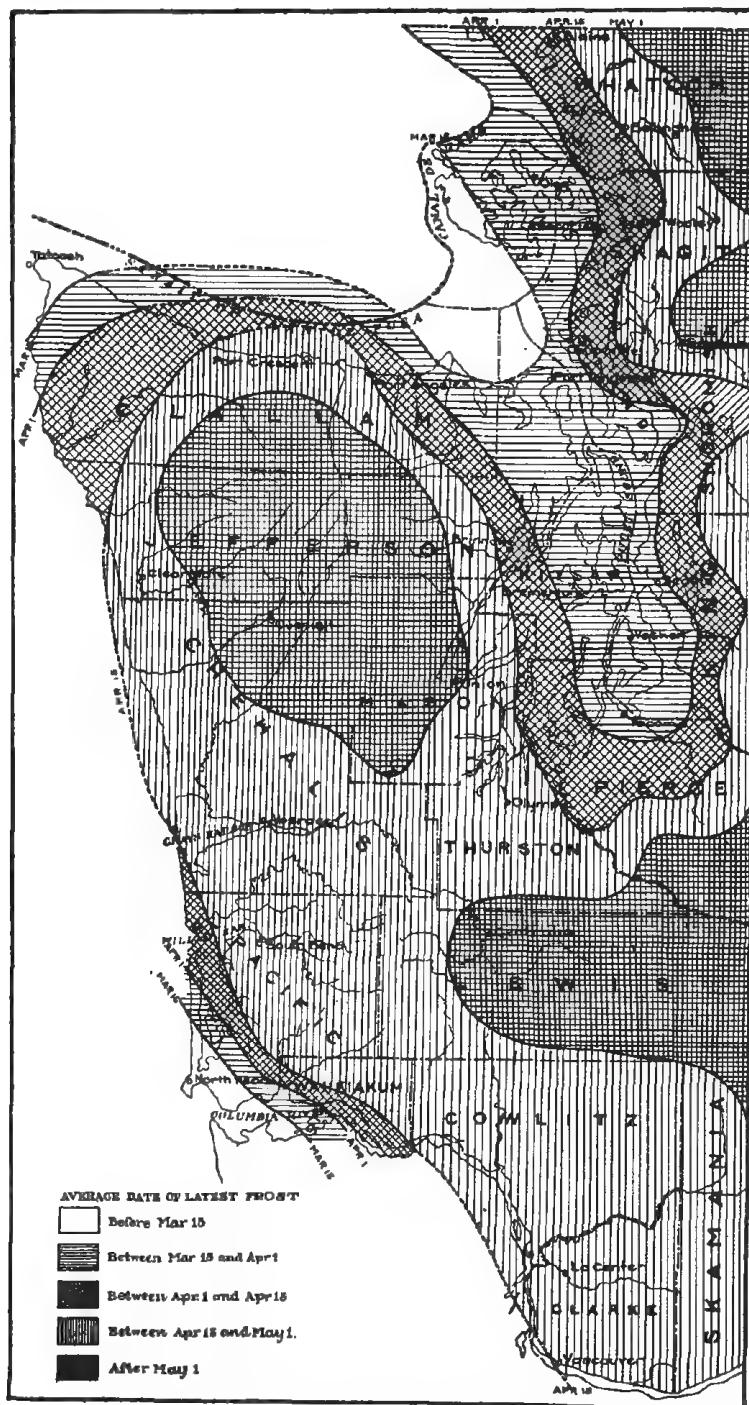


FIG. 6.—Sketch showing average dates of latest frosts in spring.

date in the fall is at North Head December 22 and Tatoosh December 10, while South Bend and Clearwater are apt to have frost about November 10. The earliest killing frost recorded is at Centralia September 8, Olympia September 11, and Port Crescent September 10.

The latest average date for spring frosts is May 6 at Centralia, May 3 at Union City, April 20 at Port Crescent, March 10 at Tatoosh, and February 9 at North Head. The latest killing frost recorded is at Centralia June 6, South Bend May 29, and Port Crescent May 21.

WINDS.

The winds of the section are prevailingly from the west, but they are modified in the summer and winter by the different relations of the high and low pressure areas over the Pacific Ocean and the interior of the continent in the two seasons. During the summer the prevailing high pressure over the northern Pacific Ocean causes northwesterly winds along the coast, while in the winter the passage of the cyclonic areas in rapid succession to the north of us and high pressure over a more southerly portion of the Pacific Ocean causes southwesterly winds. The wind direction is also modified by the topographic features. At the stations along the Strait of Juan de Fuca and northern part of the Sound the winds are generally from the west or northwest, but in the southern part of the area the winds are more from the south and west, coming into the Sound basin through the Chehalis River gap. Variable winds are caused by the passage of cyclonic and anticyclonic areas, the direction depending on the position of the station in regard to the centers of low or high pressure. Thus an anticyclonic area to the east will cause an easterly or northeasterly wind, while a cyclonic area to the north and east will cause southerly and southwesterly winds.

The winds seldom attain a velocity of more than 45 miles an hour, the average high winds in the winter blowing from 25 to 45 miles, and in the summer at a somewhat lower velocity. The total number of windy days is small, and there are fewer windy days in the summer months than during the winter months.

During the summer the west and northwest winds from the ocean are cool and usually cause cool, cloudy weather or light rainfall. The northeast and east winds coming from the interior are warm and dry, causing warm days and cool nights with the highest diurnal variation of temperature during the year.

During the winter the southwest and west winds are warm and moist, causing heavy rainfall and warm weather with very little diurnal variation in temperature. The northeast and east winds, from the east side of the Cascade Mountains, are cold and bring with them the low temperatures of the interior, causing the cold spells of the winter season.

SUMMARY.

The climate throughout the section, and especially along the coast and the Sound, is marine in character. The evenness of the temperature conditions throughout the year, the slow and rather slight changes, and the decided winter maximum in precipitation, are the most striking features of the climate. The idea that it rains all the time, even during the winter months, is decidedly erroneous. There are many clear, pleasant days during the months of maximum rainfall, and the rainy days, except occasionally when accompanied by high winds, are warm and pleasant. The conditions from May to October are ideal, with only 5 to 12 rainy days per month, few hot days, and no oppressively hot nights.

Many have ascribed this equable climate to the Japan current, but, as has been shown, the prevailing westerly winds, the cyclonic storms, and the condensation of the moisture are the chief factors in causing these conditions. The only influence that the Japan current exerts over the climate here is in the general raising of the temperature of the waters of the Northern Pacific Ocean a few degrees higher than it would be if there was no current. Even this effect would not be felt on our coast if it were not for the prevailing westerly winds. Changes of climate have also been explained by changes of position of the Japan current. In the first place, no permanent change of climate is shown by the records, and any slight differences that may be observed between two winter seasons or two summer seasons or different months can be easily accounted for by irregular variations in the path of the cyclonic storms which pass over the area. If the storms pass south of the section, the winds will be from the north and cooler weather will be the result. If the storms pass north of the section, the winds will be from the south and warmer weather will be the result.

AGRICULTURE.

For many years after the settlement of this region lumbering continued to be the only industry. A large proportion of the area surveyed is still covered with a heavy growth of fir, cedar, hemlock, and spruce. The cutting and marketing of this timber, together with the manufacture of lumber and shingles, is the principal industry in almost every county within the boundaries of the survey.

The earlier logging operations were carried on mainly along the valleys of the larger rivers or along the Sound, the waters of which afforded means of transportation. As the lumber industry increased in importance small towns and settlements grew up around the lumber mills, and soon small areas of land were put under cultivation to supply the local demand for farm produce. The first agricultural development naturally took place in the valleys of the larger streams,

because the alluvial lands were among the first to be cut over, the soils were more productive than those of the logged-off upland areas, and they could be cleared and made ready for farming with less labor and expense than areas in the uplands.

During the last 30 years, however, the rapid growth of all branches of industry and the great increase in population of both the cities and rural districts have caused a steadily increasing demand for agricultural lands. At present a large part of the valley land, the level glacial basins, and the better class of prairie land in the area has been cleared and put under cultivation.

In the rolling upland districts agricultural development has progressed more slowly. The principal factors retarding the development of these sections have been the cost of clearing the land of stumps, windfalls, and underbrush and the topography, which is rolling and less favorable to farming than the more level surface found in the valleys and basins. The last condition is especially marked in the glaciated districts, where the rolling topography, in conjunction with the porous character of the soil and subsoil, causes the drainage to be excessive. The developed areas of upland are now confined mainly to areas in the vicinity of the larger towns. As the distance from the towns increases, the areas cleared and utilized for farming occur less frequently, and a large proportion of the rolling upland in every section of the area is still in the condition known as logged-off land or is covered by the original forest growth.

The type of agriculture varies considerably in different parts of the area. In the glaciated upland districts the cost of clearing the land is so great that only such crops as will give large returns from intensive cultivation of small acreages have proved profitable. The rainfall is light during the growing season, and success on these uplands, especially on the excessively drained light sandy or gravelly types, depends largely on the use of methods tending to conserve the soil moisture.

When these upland soils are cleared for farming the land is usually burned over to remove the underbrush and smaller vegetation. This destroys the thick covering of partially decomposed organic matter overlying the surface soil. It also destroys a large part of the organic matter in the soil and leaves the land in an impoverished condition, so that very careful methods of cultivation are necessary in order to restore it to a productive state. The use of thoroughly decomposed manure and the growing and turning under of clover or field peas has proved very beneficial to the newly cleared land.

In the river valleys, basins, and small sandy prairies of the glaciated region farming is of a more extensive type. Larger areas are under cultivation, and such staple crops as oats, barley, wheat, field peas, and forage crops are grown with profit.

In the residual uplands of the southern and southwestern parts of the area the general character of the subsoil prevents the excessive drainage commonly found in the glaciated upland areas. More care is necessary to avoid damaging erosion, which begins on the steeper slopes as soon as the land is cleared of the timber and underbrush. The crops there are less likely to suffer for lack of moisture than in the glaciated region. Only a very small percentage of these uplands is as yet under cultivation. The more level areas and the smaller benches and plateaus which occur throughout the uplands are well adapted to general farming and produce very profitable yields of all crops grown. It is necessary, however, to keep clover or some other crop on the steeper slopes, especially during the rainy season, to prevent washing.

In the southern and southwestern parts of the area, as in other localities, farming is carried on more extensively in the valleys of the larger rivers, such as the Chehalis, than in the upland districts. General farming, stock raising, and dairying are carried on together and the crops grown on both the upland and alluvial soils consist chiefly of hay and small grains, used mainly as feed. There is a small acreage of orchard fruits, small fruits, and vegetables.

Dairying is rapidly becoming one of the most important agricultural industries. In every part of the area surveyed the climatic conditions and the soils seem well adapted to grasses, especially clover, and in many localities, where a variety of farm crops was formerly grown on a small area, the farms now devote a large acreage to the growing of clover and other forage crops, the sale of dairy products forming the chief source of income.

In clearing logged-off land for the growing of cultivated crops, the most expensive work is the removal of the large stumps left by the lumbermen. Where dairy farming is practiced, the new land is frequently sown to clover and other grasses and utilized for pasture, without taking out the stumps.

The mild winter climate of the area makes it unnecessary to provide warm shelter for cattle and the pastures afford good grazing during the greater part of the year.

During the earlier stages in the development of this industry the dairy cattle of the area were of low grade, but the farmers are now rapidly displacing such herds with herds of pure-bred animals.

Several creamery companies have established large plants in various parts of the area and a branch of one of these plants or some local creamery is within reach of the farmers of almost every locality.

The growing of forage crops under irrigation is practiced on a limited area in Clallam County, where dairying is the chief industry. The crops grown consist mainly of clover, oats, oats and Canada field peas mixed, and alfalfa, of which there is at this time only a

small acreage. The methods of irrigation employed, the crops grown, and average yields are taken up more in detail in another part of this report.

Poultry.—Poultry farming is also proving very profitable, and many small areas of rough, gravelly, or stony land, in various parts of the area surveyed, and especially near the larger local markets, are being utilized for this purpose. There is always a demand for poultry products at good prices and the industry is rapidly growing in importance.

Fruit growing.—Dairy products rank first in importance in every part of the area surveyed, excepting parts of San Juan County, where fruit growing is the principal industry. Fruit trees do exceedingly well on both the glacial and residual soils and many small orchards are found in every locality embraced by the survey. More attention, however, is given to fruit growing in San Juan, Island, and Thurston Counties than in any other section of the area. The trees begin bearing at an early age and the crop is seldom if ever a failure on account of late frosts or cold weather. Apples, pears, plums, prunes, and cherries are grown on a commercial scale and the fruit is of excellent quality. Small fruits, such as strawberries, raspberries, and blackberries, are grown successfully on many types of soil and produce large yields.

Other products.—Small grains are grown extensively on the alluvial valley lands and on some of the residual upland soils. Oats are the principal crop. The yields of this grain vary from 40 to 60 bushels per acre on the upland soils and from 50 to 125 bushels per acre on the alluvial soils. Wheat is grown to a limited extent. It ordinarily does particularly well on the residual upland and alluvial soils. The yields range from 20 to 40 bushels per acre, and yields of 40 to 60 are not uncommon on the alluvial soils of the river valleys. The grain, which is too soft for milling, is used mainly for stock feed. Barley and rye are also grown on a limited acreage and produce large yields. Canada field peas do well on almost every type of soil and are grown extensively as a forage crop. Clover does well on both the upland and alluvial soils, and is the principal hay crop of the area. Two cuttings are usually secured, the yield averaging about $1\frac{1}{2}$ to $2\frac{1}{2}$ tons per acre on the upland and $2\frac{1}{2}$ to $3\frac{1}{2}$ tons per acre on the alluvial soils. Irish potatoes are grown successfully on every arable soil in the area. The yields vary from 150 to more than 400 bushels per acre, depending on the character of the soil and on the cultivation of the crop.

No very large acreage is utilized exclusively for truck growing, and over the greater part of the area only those products needed to supply the demand of the local markets are grown. Many varieties of vegetables are produced in a small way throughout the area, mainly



FIG. 1.—SHOWING LOGGED-OFF CONDITION OF EVERETT STONY SANDY LOAM BEFORE CLEARING FOR AGRICULTURE.



FIG. 2.—SHOWING HEAVY GROWTH OF OATS ON EVERETT STONY SANDY LOAM UNDER IRRIGATION.

for home use, and the success attained in this indicates that the soils and climatic conditions are favorable for the production of these crops.

In some sections of the area, especially those located at a distance from the markets, improved breeds of horses, cattle, and hogs have been introduced, and stock raising is becoming an important industry.

The greater part of the area surveyed has been developed agriculturally to such a slight extent that very little is known of the special adaptation of soils to certain crops or varieties of crops. There are types of soil in the area which have never been used for farming, and there are other types in various parts of the rolling upland districts that have been cultivated only to a very limited extent. On the other hand, the farmers recognized the peculiar crop value of some of the types and type environments. The upland soils have been found best for fruits, partly because there is less danger of damage by frosts on the upland than in the alluvial valleys. The fine sandy to silty alluvial valley soils are deemed better adapted for the production of hops, hay, and small grains than any of the other soils of the area. Celery does exceedingly well on the muck soils, and the product is of excellent quality. Only a very limited acreage of alfalfa has been grown in the area, and up to the present time, with a few exceptions, this crop has proved a success only when irrigated. It is probable that the crop may be grown successfully on well-drained areas of alluvial soil. Potatoes and small fruits seem well adapted to the upland sandy or silty loams.

No systematic rotation of crops is practiced in the area, either on the upland or alluvial soils, and the fields are often planted to the same crops for many consecutive years. In the districts where dairying is the principal industry the usual crop succession is small grains followed by field peas or some other hay crop.

On the whole, the methods of cultivation are poor throughout the area. This is especially true of the glaciated regions. The topography and general character of the glacial upland soils make it necessary to use methods of cultivation which will conserve moisture and prevent the crops being damaged by drought. In many of the small glacial basins and in areas in the alluvial valleys crops are more likely to be damaged by excess of moisture than by drought. The same methods of cultivation are usually practiced on both these upland and valley soils.

The farm labor employed in the area is efficient and commands good wages. The absorption of labor by the logging companies and lumber mills, which pay even higher wages, causes labor to be scarce in every locality.

The value of agricultural land varies considerably with location, character of the soil, topography, and the extent of improvement.

Some of the land in the alluvial valleys and some of the small areas under irrigation are valued as high as \$300 an acre. The logged-off or unimproved land ranges in value from \$5 to about \$150 an acre, according to its location with respect to markets or shipping points.

Farms located in the valleys range in size from 20 to more than 160 acres. In the uplands, the land is being taken up in smaller tracts and the cultivated areas seldom exceed 20 to 40 acres.

More intensive cultivation of the soil, the use of barnyard manure on all the soils, especially the lighter textured upland types, a systematic rotation of crops, and the growing and turning under of green manure crops, such as clover and field peas, are recommended for the improvement of the soils of the area.

IRRIGATION IN WESTERN WASHINGTON.¹

The practice of irrigation in the area surveyed and in fact in that part of the State of Washington lying west of the Cascade Mountains has not been extensive. On account of the heavy annual rainfall, irrigation has in the past been considered unnecessary. A study of the distribution of rainfall throughout the year (see fig. 3, p. 20) shows that the bulk of rain falls during the months when it is not required by growing crops. During the summer months the rainfall generally is insufficient to enable crops to maintain maximum growth. Combined with the small amount of rainfall during this period, the soils of the area are for a large part excessively drained. The coarse texture of the subsoil in many types of soil does not permit the upward capillary movement or the retention of soil moisture, necessary where dry-farming methods are practiced successfully. In the case of such soils it is evident that the application of water would materially enlarge the yields and this fact has been recognized throughout the area in the constant irrigation during the dry months of gardens, lawns, and truck fields. The introduction of water by ditches on a large scale has been very successful at Sequim, in Clallam County, and it will be of interest to farmers in other portions of the area to consider the results accomplished by irrigation at this point.

SEQUIM SOILS.

Two types of soil are under irrigation—the Sequim gravelly sandy loam and the Everett stony sandy loam. The former is described elsewhere (see p. 100). It was formerly a treeless prairie. When dry farmed it produced 8 to 12 bushels of wheat and from 12 to 18 bushels of oats. It was used mainly for early spring pasture. In midsummer it became dry and barren. For some reason, a biological

¹ Prepared by H. K. Benson, of the Washington Geological Survey.

one probably, trees were unable to grow in this soil, although the gradual encroachment of the forest was becoming evident. The Everett stony sandy loam is reddish in color and lacks the high content of organic matter found in the Sequim gravelly sandy loam. This soil was originally covered with forest growth and areas now under irrigation had first to be cleared. (Pl. II, figs. 1 and 2.)

In order to consider the results accomplished by irrigation in reference to these two soils, it is desirable briefly to emphasize the physical and chemical nature of the soils. Both soils carry from 20 to 40 per cent of gravel and stones. Many of the latter were large boulders and before the prairie could be cultivated these stones were removed. Where land is now being cleared, the removal of the stones is an element entering into the cost of clearing. The results of a mechanical and chemical analyses of the fine earth of representative samples are shown in the tables following.

Mechanical analyses of Sequim gravelly sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25267.....	Soil.....	11.7	18.9	10.0	19.3	9.3	21.0	9.9
25268.....	Subsoil.....	15.9	17.8	10.4	20.6	10.8	20.1	4.3

Mechanical analysis of Everett stony sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25233.....	Soil.....	12.5	14.7	8.6	16.7	12.7	24.8	10.2

Chemical analyses of samples of the fine earth of soils under irrigation.

SEQUIM GRAVELLY SANDY LOAM.

	Per cent.
Lime.....	1.16
Phosphoric acid.....	.28
Potash.....	.46
Nitrogen.....	.33
Loss on ignition.....	25.98

EVERETT STONY SANDY LOAM.

Lime.....	1.13
Phosphoric acid.....	.48
Potash.....	.32
Nitrogen.....	.18
Loss on ignition.....	11.32

The subsoil of the Sequim gravelly sandy loam to a depth of 4 to 8 inches consists of a reddish-colored gravel and small stones, with

considerable fine material intermixed. Below this layer is a gray compact stratum of fine sand and gravel, which, at a depth of 20 to 30 inches, is usually known under the name of "hardpan." The subsoil of the Everett stony sandy loam consists of a gravelly sandy loam containing a high percentage of stone and boulders.

HISTORY OF IRRIGATION.

The first irrigation project was undertaken by the Sequim Ditch Co. during the summer of 1895. Water was taken from the Dungeness River by a main ditch 6 miles in length. The cost of construction was \$4,500. This ditch and its laterals is capable of irrigating about 4,000 acres. The Eureka Ditch Co. completed a ditch 7 miles in length in 1902. This cost \$3,000 and is capable of irrigating 1,500 acres. A third ditch, 7 miles long, was built in 1904 by the Independent Ditch Co. at a cost of \$6,000. This ditch is capable of irrigating 3,000 acres. A fourth ditch is projected at a higher level, which will carry approximately three times the volume of water now carried by the single ditch and will cover a much larger area of land for irrigation.

The total area of land under irrigation at the present is less than 2,000 acres, but the laterals are being extended, and more and more land is brought under cultivation yearly.

COST OF IRRIGATION.

The original ditches were built by the men who were to benefit by them. Each man contributed labor and some money and was assigned a proportionate number of shares. A share represents the right to the use of a miner's inch of water, though water is not at present distributed on this basis. Instead, the total supply of any one ditch is divided into a certain number of shares, and shareholders receive a corresponding proportion of water. The first cost has approximated \$1.50 a share, and 5 shares of water are required to irrigate an acre of land. Annual assessments are levied for maintenance of the ditches, amounting, on an average, to 25 cents per acre.

WATER SUPPLY AND TOPOGRAPHY.

The water is taken from the Dungeness River, which has its source in the foothills of the Olympic Mountains. The supply is kept practically constant by the melting of snowfields which drain into the river. The velocity of this stream is very great, and it therefore carries in suspension a high amount of fine earthy matter. After it is withdrawn from the river much of this material is deposited in the ditches. This clayey and silty matter acts as a

cementing material in lining the ditches, and after the first flow of water the loss from seepage in the main ditches is practically negligible. In the laterals the loss of water from seepage is considerable, perhaps as much as 25 per cent. The general slope of the land has a gradient of about 36 feet to the mile, and the velocity of the water in the ditches is somewhat greater than ordinarily. The general topography of the country is level, and little difficulty has been experienced in getting the water over the land. The method used requires the leveling of the ground and the plowing of shallow trenches with shovel plows or listers. This cost is estimated at \$5 an acre. The water is taken from the laterals and allowed to flow in the trenches until the ground becomes saturated. Irrigation consists in watering the area covered by each crop twice during the growing period.

SUBIRRIGATION.

In the lower part of the area the ground is subirrigated and a system of drainage has been installed. About 210 acres of subirrigated land are under cultivation. A considerably larger area is in timber and in a swampy condition. The soil of the subirrigated portion of the area is more loamy in texture, has greater depth, and contains less gravel and stones and a higher content of organic matter. The system of drainage now employed consists of open ditches placed along the edges of the cultivated area. In a few instances wooden drains have been installed and the ditches closed and more recently wooden pipes have been used, whereby it is possible to control the drainage and prevent it from becoming excessive during the dry season.

CROPS UNDER IRRIGATION.

The chief industry of the region is dairying and the crops in the past have conformed to this industry. (Pl. III, fig. 1.) A typical example is a 20-acre farm which is capable of supporting 12 cows and a team of horses. From 4 to 6 tons of cattle feed, such as shorts, salt, oil-seed cake, etc., are purchased for use from December 15 to June 1. From the latter date green forage is cut and takes the place of the shorts. The milk produced is put through separators and the cream sold, the skimmed milk being used to fatten hogs. During the year 1910 the average monthly income was \$10 per cow and the income from the sale of hogs was sufficient to pay for the hired help required on a 20-acre farm. The principal forage crops are clover, oats, oats and Canada field peas mixed, and alfalfa. (See Pl. III, fig. 2.) Clover is cut twice, the first cutting yielding about $2\frac{1}{2}$ tons of hay per acre and the second cutting $1\frac{1}{2}$ tons. Oat hay is largely used, yielding from 3 to 4 tons per acre. Mixed oats and peas yield from 4 to 5 tons of hay per acre. Alfalfa has recently been intro-

duced and is not old enough to get a definite idea of yields. From one second-year crop 3 tons per acre were cut and the condition of the alfalfa four weeks later indicated a yield of possibly $1\frac{1}{2}$ tons per acre for the second cutting. A third cutting might be made but could not readily be cured on account of fall rains. Alfalfa is used to a limited extent for ensilage, but more generally is pastured.

The responsiveness of the soil under irrigation may be illustrated by the yield of succession crops. In one instance the following yields were obtained from the same tract in one season: First crop of oats yielded 5 tons of green forage per acre; second crop of rye cut for green forage yielded 5 tons per acre; third crop of turnips sown broadcast yielded 4 tons to the acre.

Root crops have not been extensively grown, but from 200 to 240 bushels of potatoes per acre and from 35 to 40 tons of mangels of the Golden Tankar and Mammoth Red varieties are said to be average yields.

Fruit trees have been planted and are beginning to produce fruit of good quality. When the trees are properly cared for the yield is quite heavy, and the fruit is of good color and excellent flavor. Apples from this section were awarded prizes by the Alaska-Yukon-Pacific Exposition in 1909. Yields of 400 crates of strawberries per acre have been reported, and berries in general yield heavily.

The crop yields on subirrigated land are practically the same as on the irrigated land. Oats grown for grain yield from 85 to 90 bushels per acre, and as hay from $3\frac{1}{2}$ to 5 tons per acre. Very little information can be obtained as yet regarding the yield of the Everett stony sandy loam under irrigation. It is probable that the usual aeration and preliminary cultivation which has been found necessary in the case of land recently cleared of fir trees must be followed before maximum productiveness will be obtained. Clover hay was found to yield $2\frac{1}{2}$ tons for the first cutting the second year of cultivation, and oats for hay yielded $3\frac{1}{2}$ tons per acre. The yield of potatoes during the second year's cultivation of this tract fell slightly below 200 bushels per acre. Garden truck and small fruits seem to yield about the same as on the Sequim gravelly sandy loam, but no definite idea of yields could be obtained at the time of this survey.

GENERAL AGRICULTURAL CONDITIONS.

The advantages of this region of irrigated land are several. The Dungeness River water carries considerable fine rock flour, which acts as a supply of mineral nutrients. The larger proportion of sunshine throughout this belt adds to the color of the fruits and forces the growth of crops. The large percentage of gravel and stones in

the soil is said to be a favorable factor in absorbing heat during the day and radiating it during the night—a view which has been supported by especially heavy yields from some of the fields where the soil contains more than the average amount of stones. The conditions of soil warmth, soil moisture, and mineral nutrients are thus happily supplied in this vicinity by the irrigation of a gravelly stony soil.

Several factors, such as occasional heavy winds from the straits, the lack of transportation, except by a single line of steamers, and remoteness from a large market, have interfered with a more rapid development of this region. In spite of this the land has increased in its selling price from \$5 an acre, the usual price for "prairie" land, to \$75 to \$125 an acre, while improved irrigated land, including water rights, sells from \$250 to \$300 an acre. The Everett stony loam type sells in its unimproved condition from \$35 to \$60 an acre, but the cost of clearing in this case is considerable.

IRRIGATION IN OTHER PORTIONS OF THE AREA.

Large areas of prairie land occur in the area surveyed in 1910 as well as in the area covered in 1909. The soils of these areas are described under the Spanaway series and a comparison between the corresponding Sequim soils shows distinct differences both in the origin of the soil and the texture of the subsoil. As far as the soil is concerned, it is the opinion of the representatives of the Bureau of Soils and the State of Washington engaged in this survey that agricultural conditions might be greatly improved by the introduction of irrigation where soil depth and topography are favorable. It is believed that this general recommendation can safely be made to apply, under the limitations above cited, to all the soils of the Spanaway series, as well as to large bodies of the Everett sandy loam and Everett loamy sand.¹ The texture and chemical composition of representative samples of these soils are shown in the following tables:

Mechanical analysis of Spanaway gravelly sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
25273.....	Soil.....	Per cent. 3.8	Per cent. 7.3	Per cent. 8.8	Per cent. 27.6	Per cent. 13.8	Per cent. 23.3	Per cent. 15.5

¹ See *Irrigated Lands of the State of Washington*, Bureau of Statistics and Immigration, Olympia, Wash., p. 79.

Mechanical analyses of Everett loamy sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
22072.....	Soil.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
22073.....	Subsoil.....	1.9	16.1	21.0	26.1	13.1	10.4	11.4
		.5	10.6	27.9	47.5	5.3	4.5	3.8

Chemical analyses of the fine earth of the Spanaway gravelly sandy loam and Everett loamy sand.

SPANAWAY GRAVELLY SANDY LOAM.

	Per cent.
Lime.....	0.59
Phosphoric acid.....	.24
Potash.....	.28
Nitrogen.....	.37
Loss on ignition.....	17.96

EVERETT LOAMY SAND.

Lime.....	1.07
Phosphoric acid.....	.15
Potash.....	.21
Nitrogen.....	.12
Loss on ignition.....	8.78

SOILS.

The soils of the area have been classified broadly into 47 types, the separation being based on the texture of the soil and subsoil, the origin and method of formation, the agricultural value, and the topography. Areas occur in many of these types, as shown in the map, which differ in some respects from the soil as typically developed. These areas are usually of limited extent and represent phases of the typical soil which have been modified by local influences such as restricted drainage, erosion, accumulation of organic matter, or slight differences in topography. In a more detailed survey some of these areas would be classified as distinct soils, but in a reconnaissance the detail necessary to show each local phase or modification of the principal types can not be made. Where these areas are of sufficient extent or importance, their location, general characteristics, and agricultural value have been described in detail in the description of the type of which they are a phase, though it was impracticable to delineate them in the map.

The soils of the area have been separated broadly into 13 general groups: (1) Those soils derived directly from both glacial till and modified drift; (2) those derived directly from glacial outwash material exclusively; (3) those derived from old sedimentary deposits; (4) those derived from material deposited in shallow basins

of glacial lakes or swampy depressions; (5) residual soils of the hilly districts; (6) residual soils of the rough mountainous districts, undifferentiated; (7) soils derived from recent alluvial stream deposits; (8) sedimentary deposits in tidal estuaries; (9) alluvial soils constituting old elevated flood plain and delta deposits; (10) soils formed by admixture of recent alluvial and colluvial deposits with older glacial outwash material; (11) marine beach deposits; (12) soils of aeolian or wind-distributed origin; and (13) organic accumulations.

Soils derived from both glacial till and modified drift.—The southern boundary of glaciation crosses the area in a general northwest and southeast direction and the entire area surveyed, with the exception of a small part of Thurston County and the included portion of Chehalis County, lies within the glaciated region. This group of soils embraces the types of the upland portions of the area lying north of the boundary of glaciation, exclusive of the districts covered by the soils of group 2, derived solely from glacial outwash material. The topography is usually undulating or rolling to hilly, with the occurrence of rough mountainous districts and of areas of limited extent of gently sloping or nearly level surface constituting uneroded remnants of an earlier upland plain or plateau surface. The soils are further characterized by the general occurrence of forest cover, usually of dense or heavy character, and consisting mainly of light-textured gravelly or sandy loams underlain by deposits of sand and gravel or by compact deposits of silt or silty clay. While the parent material, in many localities, may be till, it has a stratified structure, indicating that it has been modified by water action. The soils usually contain a considerable proportion of rounded gravel, and boulders of varying size are found scattered over the surface and embedded in the soil mass. In some localities the glacial drift contains a large quantity of silt and fine sand and is comparatively free from gravel and small boulders. The silty or fine sandy loam soils usually contain quantities of small rounded iron pellets. Owing to the rolling topography and to the porous character of both the soil and subsoil of the greater majority of the soils of this group the natural drainage is usually excessive.

The soils representative of this group constitute the Everett, Clallam, and Whatcom series. Two additional related types of inextensive and local occurrence, the San Juan coarse sandy loam and the Townsend gravelly sandy loam, with regard to which the character of the parent glacial drift is undetermined, have also been included within this group. These two types depart from the others of this group in that the San Juan coarse sandy loam is treeless while the Townsend gravelly sandy loam is sparsely timbered.

Soils derived from glacial outwash exclusively.—In the southern part of the area many more or less extensive, sparsely timbered or treeless prairies occur. The soils of these prairies are composed of deposits of sand, gravel, and small rounded cobbles, laid down as glacial outwash plains. Most of these areas consist of a compact mass of rounded cobbles and gravels which have been washed clean by the action of glacial waters, covered by a layer of sand and fine gravel, with an average thickness of from 4 to 12 inches. In other areas occur deep deposits of sand almost entirely free from gravel or small bowlders. The soil derived from the coarser gravelly formation is of little agricultural value; that derived from the sandy deposits can be utilized profitably for farming.

The soils of this group found within the present survey constitute the Spanaway series.

Soils of the glacial lake basins.—The soils occupying the shallow glacial basins and poorly drained depressions occurring at intervals in various parts of the glaciated area are derived from the sediments which were deposited during the periods when these small basins were flooded for the greater part of the year by the drainage water from the surrounding country or were covered by the water of shallow lakes or ponds. These basins have been gradually filled by the material washed into them from the surrounding uplands, but the natural drainage of most of them is still very imperfect. The basin soils vary to some extent in texture, but the surface soils always contain a high percentage of silt and much organic matter. The sub-soils usually consist of a compact, impervious silty clay, but pockets and strata of sand and gravel often occur at a depth of 2 to 4 feet below the surface. Small deposits of diatomaceous earth are sometimes found in the subsoil.

The soils comprised in this group belong in the Bellingham and the Ebey's series. Only one member of each series was encountered.

Soils derived from old sedimentary deposits.—A part of the rolling uplands and the level plateau and bench lands of the southeastern part of the area is underlain by interstratified gravels, clays, and shales. These deposits overlie the tilted strata of the older formations and are thought by geologists to represent fluviatile or marine deposits of Pleistocene time. The gravels are composed mainly of rounded waterworn fragments of soft sandstone, but small rounded fragments of basalt, quartz, and shale also occur throughout the formation. A considerable quantity of iron oxide is present, giving the weathered material a characteristic red or reddish-brown color. Four types of soil—the Hoquiam clay loam, the Copalis clay loam, Montesano silty clay loam, and Montesano clay loam—are derived directly from the weathering of these deposits. The beds of gravel,

clays, and shales weather very rapidly, and the material derived from them consists mainly of silt and clay.

The Copalis clay loam, Montesano clay loam, and Montesano silty clay loam, which occupy broad plateau or level bench lands, where the level topography has caused the natural drainage to be restricted, contain a large amount of decomposed organic matter and have a dark-brown to black color. On the well-drained plateaus the percentage of organic matter in the surface material is much less, and the soils have the characteristic reddish-brown color of the original material. The depth of the weathering varies considerably on the level benches and plateaus, but beds of soft, rounded gravel are usually encountered from 3 to 10 feet below the surface.

Small local shallow basins within the soils of this group, which receive the drainage waters from the surrounding lands and remain in a wet or partially flooded condition during a part of the winter months, occur at intervals on the larger plateaus. These areas contain a large amount of decomposed organic matter, and the surface 6 to 10 inches often has the general characteristics of muck.

Residual soils of the level to hilly districts.—The residual soils are uniformly of finer texture than those derived from glacial material, consisting mainly of silty clay or clay loam. A considerable proportion of the rolling uplands in the southern and southwestern parts of the area lying outside the glaciated district is underlain by a series of shales and shaly sandstones. In some localities beds of a hard, fine-grained sandstone occur, but this has entered very little if any into the formation of the soils.

Overlying the harder sandstone is a later formation consisting mainly of fine-grained, argillaceous sandstone and arenaceous shale, which break down rapidly on exposure, forming a brown to reddish-brown silt loam or silty clay loam. This formation has weathered to a depth of many feet, but the surface material erodes so rapidly that the soils on the steeper slopes are usually shallow and areas of rock outcrop occur frequently. These impure sandstones and shales, classified by geologists as Tertiary rocks, probably of Pliocene and Miocene age, give rise to the soils of the Melbourne series.

In the San Juan Islands occur inextensive areas of outcropping rocks, probably metamorphosed sandstones, which upon weathering give rise to a dark-colored sandy material. This has been intermingled and modified by glacial drift material, forming a soil not previously recognized and here designated as the Dallas coarse sandy loam.

Residual soils of the rough mountainous districts, undifferentiated.—The soils of this group are derived mainly from the weathering of consolidated rocks. With this residual material is included a small amount of glacial detritus, sometimes occurring locally in

minor pockets or basins, or as a shallow veneer over the underlying rocks. The soils of this group are derived principally from hard, fine-grained sandstone and basalt and occur extensively in the region occupied by the Olympic Mountains and in the Black Hills district in the southern part of the survey. They are often shallow, and the content of fragmental rock of both soil and subsoil is high. Along the lower slopes and foothills the soils are composed locally of a mixture of glacial and residual material.

The residual soils of the rough mountainous districts vary in texture from sandy loams to silt loams or silty clay loams. They usually carry a large quantity of angular rock fragments, with at times some gravel and rounded or subangular boulders. Small areas of relatively level topography occur and these are comparatively free from rock and could be profitably used for agriculture, but they are usually surrounded by extensive areas of such rough and broken topography or of such high rock content that they are of little or no value for farming.

No attempt has been made to differentiate all the individual soil types comprised in this group. They have been mapped together as the Olympic loams.

Associated with the residual soils of the rougher mountainous districts of the area surveyed, particularly in San Juan County and about the foot of the Olympic Mountains, occur extensive bodies of soils derived mainly from the glacial drift. They are of variable texture, contain gravel and glacial boulders, and while related to the Olympic loams in physiographic occurrence, have from the standpoint of origin been included as the Everett stony loams in the Everett series previously noted under group 1. No attempt has been made to separate individual soils which are described as the Olympic loams.

Recent alluvial soils.—The alluvial soils are derived from material deposited by flood waters along the flood plains of the principal streams. The soils along the rivers traversing the glaciated part of the area differ from those laid down by the streams draining the region of residual soils. In the glaciated region the river valleys were first covered by a deposit of fine sand, but except for a narrow strip or low ridge of fine sandy soil which borders the present channel of the streams these deposits have been covered by more recent sediments of silt and clay, so that the fine silty surface soils are usually underlain at a depth of from 1 to 6 feet by a compact fine sand or fine sandy loam. Soils of this character have been placed in the Puget series.

The alluvial soils occupying the valleys in the residual belt are derived from the deposition of the silt and clay eroded from the

residual upland types. There is frequently a narrow strip of sandy loam bordering the banks of the present stream channels, but the material deposited in the remainder of the valleys is composed principally of silt and clay. The subsoils of these types are usually heavier than the surface soils and consist mainly of a compact silty clay loam or silty clay. These soils are members of the Chehalis and the Eld series.

Tidal estuarine deposits.—Small areas of tidal flats, only slightly elevated above sea level, occur at the mouths of some of the larger rivers. The silt, clay, and fine sand held in suspension by the waters of the river have been deposited in the shallow bays at their mouths, eventually forming marshes, which have gradually been built above tide level by continued deposition. Areas of this character are mapped as tidal marsh.

Older alluvial deposits.—In Clallam County there is an ancient alluvial deposit which was formed by the Dungeness River before it had cut its channel to the present level. The river, rising in the high mountains just south of the area, had considerable fall until it reached the narrow level bench land lying between the foothills of the mountains and the coast. Here the water spread out over the level area, depositing the coarser material as an alluvial fan over the land adjacent to the point where the river reached the level plain and depositing the finer sediments of silt and fine sand over the adjacent flooded areas. Several channels have been formed and abandoned by this stream, but its present channel is considerably below the level of this old flood plain, and none of the land is subject to overflow except a small area immediately along the river near its outlet. The soils embraced in this group are of the Dungeness series, of which two members, the fine sandy loam and the silt loam, have been recognized, and of the Sequim series, which is represented by a single type.

Soils derived from mixed glacial and alluvial material.—The soils falling under this group occur in the southeastern part of the area. They are of limited extent. The surface material is derived mainly from soils of the Melbourne and the Olympic series through erosion of the more elevated areas and deposited by small, often intermittent, streams along the margins of larger valleys. The underlying material consists partly of older, reworked glacial outwash gravels. These deposits sometimes closely approach the surface or appear in the soil material. The soils and subsoils are of light grayish brown to reddish-brown color. They are classified as the Elma series.

Marine beach deposits.—The beach deposits consist of narrow strips of sands and gravels which have been formed by the action of

the waves along the shores of some of the small bays and inlets of Puget Sound. These deposits are of limited extent and are partially submerged by high tides. They are shown in the map as Coastal beach.

Eolian deposits.—The eolian deposits occur along the coast of the Pacific near the entrance to Grays Harbor. They consist principally of sand. This was first thrown up along the coast by the action of the waves and later drifted inland by the winds. In places it forms typical dunes entirely free of vegetation. Farther back from the coast the areas are sparsely timbered. The eolian materials have been mapped as Dunesand and Westport fine sand.

Organic accumulations.—Some of the local lake basins or depressions and poorly drained valleys are occupied by deep accumulations of organic matter, resulting from the decay of rank water-loving vegetation. Such areas have been mapped as Muck and Peat. The material is in varying stages of decomposition, the more thoroughly decomposed forming the Muck and the less thoroughly decomposed the Peat. The two grades of material often occur in small intermingled areas and no attempt has been made in this survey to separate them.

The agricultural value of the various types of soil encountered in the area varies considerably. The sandy loams and gravelly sandy loams of the glaciated uplands are successfully cultivated, but they are excessively drained and very careful methods of cultivation are necessary to prevent the partial or total loss of crops on account of the lack of moisture. The stony loams occurring in the mountainous sections are of little agricultural importance and are best adapted for forestry.

The soils derived exclusively from the coarser glacial outwash are at present of low agricultural value, but there is a possibility that small areas in the valleys of the smaller streams may eventually be irrigated and thus be made valuable for agriculture. The coarse gravelly texture interferes with the thorough cultivation of the land and the porous character of the subsoil causes the natural drainage to be excessive. In some localities in which the subsoil is made up to a greater extent of fine material the more level areas have been utilized very profitably for the growing of fruits and for pasturage. The results obtained on the irrigated gravelly soils in Clallam County indicate that where soils of this character can be supplied with water they will produce very profitable yields of all crops grown.

The soils occupying the shallow upland basins are well adapted to farming. The land can be cleared at comparatively small cost, but the drainage is usually inadequate and artificial drainage is necessary in order to obtain the best results.

The residual soils of the level to hilly upland districts are as a whole more productive than those of the glaciated region. Those occupying the more level bench lands and plateaus are well adapted to farming and produce very profitable yields of all crops grown. The land occupying the slopes of the rounded hills and ridges, however, is frequently damaged by erosion.

The undifferentiated residual soils of the rough mountainous districts are of little agricultural value and extensive areas occur that are fit for reforestation only.

The alluvial types occupying the valleys and terraces have a level to gently undulating topography and are considered the most productive soils of the area. Much of the land, however, is subject to overflow during the winter or early spring months.

The sand forming the limited areas of Coastal beach is classed as nonagricultural land. The sandy soils of eolian origin are also of very little agricultural value; the drifting sand dunes can not be used for farming, but a small acreage of the more level areas of fine sand is under cultivation.

The following table gives the actual and relative extent of each of the soil types encountered in the area:

Areas of different soils.²

Soils.	Olympia sheet.	Port Townsend sheet.	Total.	Per cent.
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	
Everett gravelly sandy loam.....	232,704	351,488	633,344	23.1
Sandy phase.....		49,152		
Melbourne silty clay loam.....	459,200	2,304	485,056	17.7
Dark phase.....	23,552			
Olympic loams.....	127,232	160,000	287,232	10.4
Everett gravelly loamy sand.....	83,712	37,120	265,472	9.7
Heavy phase.....	83,968	60,672		
Hoquiam clay loam.....	204,800		204,800	7.4
Everett loamy sand.....	27,136	81,920	109,056	4.0
Clallam gravelly fine sandy loam.....		96,256	96,256	3.5
Spanaway gravelly sandy loam.....	83,456		83,456	3.0
Bellingham silt loam.....	32,000	46,592	78,592	2.9
Everett fine sandy loam.....	9,728	63,232	72,960	2.6
Everett stony loams.....		67,840	67,840	2.5
Chehalis silty clay loam.....	67,584		67,584	2.4
Everett stony sandy loam.....	34,048	10,752	44,800	1.6
Everett silt loam.....	35,584	1,280	36,864	1.3
Chehalis silty clay.....	26,112		26,112	.9
Copalis clay loam.....	23,808		23,808	.8
Muck and Peat.....	8,704	13,824	22,528	.8
Everett sandy loam.....		18,432	18,432	.7
Montesano silty clay loam.....	11,776		13,056	.5
Mucky phase.....	1,280			
Clallam very fine sandy loam.....		11,520	11,520	.4
Spanaway loamy fine sand.....	9,984		9,984	.3

Areas of different soils—Continued.

Soils.	Olympia sheet.	Port Town- send sheet.	Total.	Per cent.
	Acres.	Acres.	Acres.	
Dungeness fine sandy loam.....		8,192	8,960	0.3
Dark sandy phase.....		788		
Puget silt loam.....	6,656	2,048	8,704	.3
Westport fine sand.....	7,680	.....	7,680	.3
Puget fine sandy loam.....	4,096	3,072	7,168	.2
Spanaway loamy sand.....	4,864	.....	4,864	.2
Ebeys sandy loam.....		4,864	4,864	.2
Eld silty clay loam.....	2,560	1,792	4,352	.1
Clallam fine sandy loam.....		4,096	4,096	.1
Montesano clay loam.....	4,096	.....	4,096	.1
Elma loam.....	3,840	.....	3,840	.1
Dungeness silt loam.....		3,840	3,840	.1
Elma gravelly sandy loam.....	3,584	.....	3,584	.1
Townsend gravelly sandy loam.....		2,560	2,560	.1
Sequim gravelly sandy loam.....		2,304	2,304	.1
Dunesand.....	2,304	.....	2,304	.1
Coastal beach.....	64	1,792	1,856	.1
Everett coarse sand.....	1,280	256	1,536	.1
Whatcom silt loam.....		1,536	1,536	.1
Dallas coarse sandy loam.....		1,280	1,280	.1
Chehalis clay.....	1,280	.....	1,280	.1
Puget silty clay loam.....	1,024	256	1,280	.1
Tidal marsh.....	512	512	1,024	.1
San Juan coarse sandy loam.....		768	768	.1
Puget silty clay.....		768	768	.1
Clallam silt loam.....		512	512	.1
Chehalis loam.....	512	.....	512	.1
Total.....	1,630,726	1,113,600	2,744,320	.....

SOILS DERIVED FROM BOTH GLACIAL TILL AND MODIFIED DRIFT.

EVERETT SERIES.

The types in the Everett series have light-brown to reddish-brown surface soils and light-brown to gray subsoils. The surface material, except in case of the silt loam, is sandy and usually contains considerable quantities of gravel, though there is enough silt and clay mixed with the coarser material to give the types a loamy texture.

Soils of this series for the most part occupy rolling upland country. Relatively small areas, with rough, mountainous topography on the one hand or with level topography on the other, are included in the general region. The several soil types have been derived mainly from deposits of sand and gravel, with occasional beds of silt, in many cases stratified.

The natural drainage of the majority of the soils of this series is excessive.

The Everett soils support a heavy growth of fir, hemlock, spruce, and cedar.



FIG. 1. DAIRY FARM NEAR DUNGENESS.



FIG. 2.—SHOWING HEAVY YIELD OF FORAGE CROPS SECURED ON SEQUIM PRAIRIE SOIL.



FIG. 3.—WHEAT FIELD ON BELLINGHAM SILT LOAM NEAR COUPEVILLE, WHIDBEY ISLAND, ISLAND COUNTY.

[A yield of 115 bushels per acre has been secured on a portion of this tract. This is said to be the largest yield ever secured in the United States. Wheat grown in this part of Washington is not good for milling purposes.]

EVERETT COARSE SAND.

The Everett coarse sand consists of about 12 inches of grayish-brown to yellowish-brown coarse sand, resting on coarse sand of somewhat lighter color. The first 2 or 3 inches usually contain some organic matter, which gives this layer a color darker than that of the underlying soil, but the structure of both soil and subsoil is very loose and porous. In places considerable quantities of coarse quartz particles give the soil a somewhat lighter color than that characterizing other Everett types.

The Everett coarse sand is glacial in origin, being composed of materials intermediate in grade between the fine gravels and the loamy sands. Only a small area of the type is found; four small bodies in the vicinity of Lake St. Clair, in Thurston County, and another near Tuckeys, in Jefferson County. The topography ranges from fairly level to hilly. The body in Jefferson County occupies a slope leading down to Port Discovery and is too rough for easy cultivation.

The Everett coarse sand has a low agricultural value, on account of its porous structure and consequent inability to retain moisture. Only a few acres of the type have been cleared and put under cultivation, though practically all of it has been logged off.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Everett coarse sand:

Mechanical analyses of Everett coarse sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25229.....	Soil.....	16.9	45.9	15.5	6.2	1.4	9.1	4.8
25230.....	Subsoil.....	13.7	43.9	20.8	9.5	1.5	6.8	3.2

EVERETT GRAVELLY LOAMY SAND.

The Everett gravelly loamy sand consists of 8 to 10 inches of light-brown to light reddish brown loamy sand or light sandy loam containing a high percentage of small glacial gravel. The surface, for 3 or 4 inches, is usually dark brown in color, owing to the accumulation of organic matter in this part of the soil. The subsoil, from 10 to 36 inches, consists of gray to light-brown loamy sand, lighter in color and texture than the surface material. A considerably higher proportion of coarse gravel and cobblestones is found in the subsoil than in the soil, and as a result the type is porous and unless carefully cultivated crops are likely to suffer quickly from drought. As a rule the gravel and cobbles are not present in the surface soil in sufficient quantities seriously to interfere with cultivation, though in a

few areas where the type approaches bodies of the Everett stony sandy loam the proportion of stone will make tillage more or less difficult.

Areas of this type are widely distributed. It is found in a number of small bodies in nearly all of the counties surveyed. The largest bodies occur along the southern line of Kitsap County, along the Black, Nisqually, and Deschutes Rivers in Thurston County, in the vicinity of Lake Cushman, and in the southwest corner of Mason County. Smaller bodies are found in the eastern part of Chehalis County; near Port Townsend, Chimacum, and Hadlock, in Jefferson County; and near Dungeness, in Clallam County.

The Everett gravelly loamy sand is an upland glacial soil deposited by melting ice and in places modified by glacial streams. The topography varies from fairly level to gently rolling and broken. The chief areas of level topography occur near Glenwood, in Kitsap County; in the vicinity of Little Rock, in Thurston County; and in the eastern part of Chehalis County. The areas of broken topography are found chiefly on slopes leading down to rivers or to the Sound.

The original forest growth consisted largely of fir, hemlock, spruce, and salal.

Owing to the porous nature of the type and the consequent danger of injury from drought, very little of it is under cultivation. The crops best suited to this soil are those which require intensive methods of farming. The soil therefore is not well adapted to clover, alfalfa, or any other hay crop, but finds its best use in the growing of vegetables, berries, and fruits.

Everett gravelly loamy sand, heavy phase.—The Everett gravelly loamy sand, heavy phase, consists of 6 to 10 inches of reddish-brown to almost black loamy sand, containing a high percentage of fine glacial gravel. The surface material to a depth of 3 or 4 inches carries a relatively large proportion of partially decayed organic matter and is much darker and more loamy than at a lower depth. The sub-soil consists of light-brown to reddish-brown light sandy loam or sand, with a higher percentage of gravel than is found in the soil. Though the soil has a very loose, porous structure it is rather hard to cultivate on account of the large content of gravel. In many places it closely resembles the Everett gravelly sandy loam, differing only in being slightly heavier, darker in color, and more gravelly.

The Everett gravelly loamy sand, heavy phase, is composed of fine materials laid down over coarser sands and gravel. Subsequently considerable organic matter has accumulated in the surface material. This is largely responsible for its loamy texture and dark color.

Areas of this phase of the Everett gravelly loamy sand are widely distributed in Mason County. The largest body occupies the greater part of several townships lying west and north of Shelton. Another body 4 or 5 miles wide extends along the north side of Hood Canal in a northeasterly direction into Kitsap County.

In topography the heavy phase of the Everett gravelly loamy sand varies from almost level to rough and broken. West of Shelton and in the vicinity of Matlock the type occupies a broad upland flat of level to gently undulating surface. Along Hood Canal and in the southern part of Kitsap County the surface is quite broken. Owing to the gravelly nature of the soil and subsoil, this phase of the type is very porous and droughty. This is especially true of the hilly areas.

Fir is the chief timber growth of the Everett gravelly loamy sand, heavy phase, but the stand is usually not so heavy as on other soils of the Everett series. There is also a lighter growth of salal, giving the forest a more open appearance than is common in the region. Hemlock, spruce, vine maple, and in the lower areas a little cedar are also found on areas of this soil.

On account of its droughty nature only a very small acreage of the heavy phase of the Everett gravelly loamy sand is under cultivation. It is necessary to practice the most careful methods of conserving moisture. With proper culture fruits and berries could probably be produced successfully, but where the surface is rough and broken it is doubtful if the crop returns would justify the expense of clearing and cultivating the land. Along the East Fork of the Satsop River, in the western part of Mason County, a considerable body of the soil may be irrigated. With irrigation the soil would be adapted to a wide range of crops and would doubtless be among the most productive in the area.

At present the value of this phase of the Everett gravelly loamy sand is determined largely by the timber growth. Some of the logged-off areas are on the market at \$10 to \$25 an acre. The cost of clearing such land is considerable.

EVERETT LOAMY SAND.

The soil of the Everett loamy sand consists of a light-brown loamy sand 10 to 15 inches deep. In texture the sand is fine to medium. A considerable quantity of rounded glacial gravel occurs on the surface and mixed with the soil. The subsoil consists of a gray loamy sand, slightly coarser in texture than the surface soil. A variable content of rounded gravel is present, and pockets and strata of sand and gravel often occur, giving the subsoil the general appearance of stratification.

More or less extensive areas of this type occur at intervals throughout the glaciated uplands. It has in general a gently rolling surface, but also occurs as narrow strips along the slopes of the hillsides bordering some of the larger alluvial valleys. As is the case with the other light-textured glacial soils, the natural drainage is excessive. When intensively cultivated the more level areas produce very profitable yields of fruits, small fruits, and vegetables.

Only a small part of this type is under cultivation, the greater proportion being still covered with forests of fir, cedar, hemlock, and spruce or lying in the undeveloped state known as "logged-off land."

When cultivated it is necessary to use every means to conserve the moisture, and even with such precautions the crops frequently are damaged by drought.

The Everett loamy sand is derived from the weathering of coarse sandy glacial drift, in places modified during the period of deposition through the action of glacial waters.

If thoroughly cultivated, land of this type produces very profitable yields of strawberries and other small fruits. Small orchards located on the type also do well with proper attention. Large yields of apples, pears, plums, prunes, and cherries are secured. The Everett loamy sand is better adapted to crops that require intensive cultivation and can be profitably grown on a small acreage than to general farm crops, such as hay and small grains.

EVERETT FINE SANDY LOAM.

The soil of the Everett fine sandy loam is a yellowish-brown to brown light textured fine sandy loam with a depth of 18 to 24 inches. Scattered through the soil are found small reddish-brown iron pellets. This surface material rests upon a light-brown to gray fine sand or fine sandy loam, sometimes of rather compact structure. Along the streams both soil and subsoil are usually considerably coarser in texture and somewhat looser in structure. Pockets and thin strata of coarse sand and gravel are frequently encountered below the third foot, giving the deeper subsoil a stratified appearance. Several small depressions of Muck and Peat, too small to be shown on a map of this scale, have been included with the type.

The Everett fine sandy loam is derived, through weathering, from deposits of glacial drift reworked and stratified or obscurely stratified during the period of deposition by glacial streams.

A number of bodies of Everett fine sandy loam are shown in the map. The largest occurs in Jefferson County in the vicinity of Port Ludlow, Center, Chimacum, and Fairmount. Another large body embracing approximately 15 square miles is found southeast of Olympia, in Thurston County. A few small bodies lie in the vicinity of Sequim and Port Angeles in eastern Clallam County.

The topography varies from level to rolling. A characteristic feature of the body near Olympia is the frequent occurrence of rounded "kettle holes" with steep slopes and from 50 to 200 feet deep. Otherwise this body is comparatively level or at most only gently rolling. In general the surface slope and the rather porous subsoil make the drainage rapid and complete, though not so excessive as in case of the coarser textured soils of the series.

The native vegetation consists chiefly of fir, cedar, and spruce, with a dense undergrowth of salal and brakes. Except for the body in Jefferson County, which is still largely occupied by a valuable growth of timber, the type has been largely logged off. Only a small acreage is under cultivation. This is found chiefly in the vicinity of Olympia, where, under intensive methods of cultivation, very good results have been secured in the growing of small fruits, peas, potatoes, and other vegetables, and clover hay and oats. The yield of oats ranges from 40 to 60 bushels per acre, clover hay from $1\frac{1}{2}$ to 2 tons per acre, and potatoes from 150 to 300 bushels per acre. Strawberries have also proved to be a very profitable crop on this soil, the yield in a favorable season reaching 300 crates per acre.

Improved farms composed of this type of soil are held at \$100 to \$250 an acre; unimproved tracts can be purchased for \$10 to \$50 an acre.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Everett fine sandy loam:

Mechanical analyses of Everett fine sandy loam.

Number.	Description.	Fine	Coarse	Medium	Fine	Very fine	Slit.	Clay.
		gravel.	sand.	sand.	sand.	sand.		
25221.....	Soil.....	0.0	1.8	3.5	26.1	40.0	23.4	5.0
25222.....	Subsoil.....	.4	4.5	16.2	36.5	18.3	18.8	5.1

EVERETT STONY SANDY LOAM.

The soil of the Everett stony sandy loam consists of 12 inches of yellowish-brown to reddish-brown sandy loam of coarse to medium texture, containing large quantities of rounded glacial gravel and boulders ranging from 2 inches to a foot in diameter. These are also scattered over the surface of the areas. The subsoil is a light-brown to gray coarse sand or loamy sand, usually containing a higher percentage of stones and gravel than the soil. The type as mapped includes small areas of Bellingham silt loam and muck which, because of their small extent, were not separated. At Sequim and in several other localities throughout the area the surface of the type contains a considerable quantity of organic matter. In such

cases the soil is more loamy and somewhat darker than in most of the areas. The large quantity of glacial boulders in the soil make much of the type difficult to cultivate. In the level less stony areas where the stones can be cheaply removed, as has been done in the vicinity of Sequim, the type is easily handled and yields well.

Areas of this type occur in all the mainland counties of the area. The largest bodies are found in Mason County between the Satsop River and Shelton and about 2 miles west of Potlatch. Other important bodies lie at Sequim, Port Angeles, Quilcene, and along the upper portions of the Deschutes and Nisqually Rivers.

The Everett stony sandy loam is derived from glacial deposits, modified by the removal of the greater proportion of the fine material by swiftly flowing water. The type, in the main, has a level topography. In Thurston County much of it is somewhat rolling, the surface being made up of low, rounded hills and intervening depressions. Both soil and subsoil are open and porous and the type is excessively drained. Crops suffer from drought.

The native vegetation consists chiefly of fir, hemlock, and some small oak, and the greater part of the area is still covered by the original forests or is in the logged-off state. Because of the stony character of the soil, the rougher areas could probably be most profitably used for the production of timber. A small area is under cultivation. A valuable body has been cleared at Sequim and placed under irrigation. Here excellent yields of a wide range of crops, including oats, clover, alfalfa, and Canadian field peas, are being secured. Oats cut for hay yield from 3 to 4½ tons per acre. Clover averages from 2½ to 3 tons per acre, though higher yields are reported. Potatoes return about 200 bushels per acre. Land of this type in this vicinity under irrigation is held at from \$200 to \$300 an acre, though much of the unimproved type in more remote districts is on the market at from \$5 to \$10 an acre. The cost of clearing such land is high.

The results of a mechanical analysis of a sample of the soil of the Everett stony sandy loam are given in the following table:

Mechanical analysis of Everett stony sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25233.....	Soil.....	12.5	14.7	8.6	16.7	12.7	24.8	10.2

EVEBETT GRAVELLY SANDY LOAM.

The Everett gravelly sandy loam occupies the greater proportion of the rolling uplands in the glaciated sections of the area. The

soil consists of a light-brown to reddish-brown sandy loam containing a large amount of small rounded iron pellets and having a depth of 10 to 15 inches. The presence of the pellets has given the soil the local name of "shot clay." The soil also contains large quantities of gravel. The subsoil consists of a mass of rounded glacial gravel embedded in a medium to coarse gray sandy loam. The texture of the subsoil often varies considerably within small areas. In many localities it has been modified by water action, and in such cases has the general appearance of being stratified. Gravel, coarse sand, fine sand, and silt occur in beds or pockets, or in layers varying from 1 to 5 feet in thickness. Several more or less extensive areas of a sandy phase of the type occur in various sections of the area surveyed. The soil in these areas is not so loamy, and is usually slightly lighter in color than the typical soil. The subsoil contains less gravel and a higher percentage of coarse sand. The phase represents a soil intermediate between the typical Everett gravelly sandy loam and the Everett loamy sand, but it has more of the general characteristics of the gravelly sandy loam and is closely associated with this type. For these reasons it has been mapped with the latter. The principal areas are shown in the map by means of a symbol. The larger areas occur in the northern part of Kitsap County. Smaller bodies are found in various parts of the glaciated region.

As a whole, the Everett gravelly sandy loam is rolling to gently rolling, but near the foothills, in the mountainous district, it becomes rough and hilly. It also occupies some of the bench lands and small upland plateaus. Here the topography is comparatively level. The coarse porous subsoil promotes drainage, and it is necessary to use every precaution for the conservation of the soil moisture, in order to cultivate the land with any degree of success. This soil is not well adapted to the growing of general farm crops. It is most successfully utilized for such crops as yield large returns from the intensive cultivation of small acreages.

The soil is derived from deposits of glacial drift composed mainly of various grades of sand and gravel, with occasional compact deposits of silt or silty clay.

In agricultural value the Everett gravelly sandy loam varies considerably and is dependent mainly upon the topography and moisture conditions. When the topography is comparatively level or gently rolling and the soil is cultivated very intensively, very fair yields of all crops are secured, but where the topography is rough and broken, causing the natural drainage to be excessive, and on areas which are not thoroughly cultivated the yields obtained are very small, and a total failure of crops is not uncommon.

Only a small percentage of the area occupied by this type is at present under cultivation. Most of it is in the undeveloped state known as "logged-off land" or covered with the original forests. With intensive cultivation Irish potatoes, orchard fruits, strawberries and other small fruits, and vegetables give profitable yields. Clover also does exceedingly well on this soil, and the land is often sown to clover and utilized for pasture immediately after the logs and underbrush have been cleared away and before the stumps have been removed.

The logged-off land is valued at from \$10 to \$100 an acre, according to its location, while some of the improved land is valued at from \$100 to \$300 an acre.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Everett gravelly sandy loam:

Mechanical analyses of Everett gravelly sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
14085, 14087, 22082, 22084.	Soil.....	2.7	8.2	6.1	21.0	15.5	32.4	13.6
14086, 14088, 22083, 22085.	Subsoil..	2.5	8.4	7.5	21.2	18.5	29.4	12.4

EVERETT SANDY LOAM.

The soil of the Everett sandy loam consists of about 15 inches of light-brown sandy loam, containing a considerable, though lower, percentage of gravel than the Everett gravelly sandy loam. The subsoil to a depth of 36 inches varies from a light sandy loam to loose gray sands of various grades, containing considerable quantities of fine and coarse gravel. A few glacial boulders are found scattered over the surface, but they do not occur in sufficient quantity to influence the agricultural value of the land or to interfere with its cultivation.

Large areas of the Everett sandy loam occupy the upland districts of Whidbey Island. The topography is rolling to hilly, but the hilltops are usually flat or at most gently rolling, forming more or less extensive irregular-shaped upland plateaus.

The open, porous soil and subsoil result in excessive drainage, and crops are subject to serious injury by drought unless every precaution is taken to maintain a supply of moisture in the soil.

The soil is derived from the weathering of deposits of modified glacial drift consisting principally of beds of fine to medium sands, coarse sand, and gravel.

Only a limited acreage of this type is at present under cultivation, the greater proportion being logged-off land or still covered by origi-

nal forest. It is not well adapted to general farming. Where small areas are cultivated intensively it produces very fair yields. Irish potatoes, one of the leading crops, yield from 100 to 200 bushels per acre. When well cultivated, orchards do exceedingly well, and large yields of apples, pears, cherries, plums, and prunes are always secured. Small fruits, especially strawberries, also do well on the well-cultivated land.

The average results of mechanical analyses of samples of the soil and subsoil of the Everett sandy loam are given in the following table:

Mechanical analyses of Everett sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
13180, 13182.....	Soil.....	14.8	21.1	13.6	18.2	8.2	13.2	10.6
13181, 13183.....	Subsoil.....	11.1	25.8	16.9	28.1	7.6	5.3	4.9

EVERETT STONY LOAMS.

The texture of the surface soil in areas mapped as Everett stony loams varies considerably within short distances. The prevailing soil is a light-brown to reddish-brown loam to silty loam, with an average depth of 10 to 15 inches. Gravel and glacial boulders of various sizes are scattered over the surface and mixed with the soil. In some small areas from 30 to 60 per cent of the surface is occupied by stones. On the other hand small areas occur on many of the more level benches and terraces which are almost entirely free from gravel or rock fragments. Here a deep loamy soil, which could be profitably utilized for farming, is found. On the steeper mountain slopes the soil forms only a shallow covering over the underlying rock and contains a large amount of sand, rock, and gravel. Pockets of heavy silty glacial till are also found in the deeper subsoil along the bench lands or lower ridges. Along many of the steeper slopes even the shallow soil covering has been entirely removed by erosion and extensive areas of rock outcrop occur.

The subsoil consists of a gray, heavy, sandy loam or loam containing a large amount of gravel, small stones, and boulders. On the steeper slopes the underlying rock is usually encountered at a depth of from 2 to 5 feet.

The Everett stony loams occupy the rough, hilly, and mountainous districts of the glaciated region. The largest areas are located in San Juan County, and smaller areas occur in the foothills of the Olympic Mountains.

The topography of the greater proportion of this group of soils is rough and broken. Small comparatively level benches and plateaus

occur at intervals, but they are usually of small extent and the country surrounding them is so rough and hilly that many of them are almost inaccessible.

The porous subsoil, together with the rough and hilly surface, causes rapid seepage, and percolation of the rain water and drainage is too thorough. After the land is cleared of the forest trees and undergrowth both the soil and subsoil remain in a dry condition during the greater part of the summer months. Drainage of the small areas occupying the bench lands or gently rolling plateaus is less excessive, and with proper handling the soil will retain sufficient moisture for the growing of crops. The material from which the Everett stony loams are derived consists mainly of glacial drift, but the glacial deposits are very shallow on the higher elevations, and material derived, through weathering, from the underlying rocks has entered into the composition of the soil to a considerable extent.

Only a very small acreage of the Everett stony loams has been cultivated. Some of the more level bench lands or coves have been utilized very successfully for fruit growing. Small areas have also been used for the culture of small fruits, potatoes, and vegetables. The rough, broken topography limits the area suitable for agriculture.

EVERETT SILT LOAM.

The Everett silt loam consists of 12 to 15 inches of grayish to light-brown silt loam, containing a high percentage of reddish-brown iron pellets. When dry the surface has an ashy-gray appearance. When wet the soil is sometimes rather compact, enough clay being present to make it sticky and adhesive. The subsoil is a compact, gray silt loam or silty clay loam, frequently marked with reddish-yellow iron stains. At 2 to 5 feet pockets of sand of various grades are occasionally encountered. These are underlain by coarser sands resting on a bed of gravel. At times the surface material also contains small amounts of gravel. Isolated areas of Everett gravelly sandy loam are included within the type, but because of their small extent they were not differentiated on the accompanying soil map.

The type is derived from the finer material of the glacial till and outwash deposits. The main bodies are found bordering inlets of the sound in northern Thurston and southeastern Mason Counties and on most of the peninsulas and islands in this locality. The largest and most important of these occur on the peninsula between Henderson Inlet and Budd Inlet, between Eld Inlet and Budd Inlet, on Hartstine and Squaxin Islands, and in the vicinity of New Kamilche, Arcadia, and Grant. Other small less typical bodies are found northwest of Matlock and southeast of Rainier.

The surface of the Everett silt loam is level to gently rolling. The type occurs as upland flats or level plateaus ranging in elevation from

a few feet to 100 feet or more above sea level. Except for the depressions and more level areas the drainage is fairly good. It is in no case excessive, as is so frequently the case with the other Everett types.

Only a small percentage of the Everett silt loam area is under cultivation. The chief crops are clover, oats, and fruit. Because of its ability to retain moisture, this is one of the best upland types in the area for the production of clover, the yields secured ranging from $1\frac{1}{2}$ to 3 tons per acre. Oats yield well, much of the crop being cut for hay. When properly cared for, apples, pears, plums, cherries, and strawberries do well on the type, though few commercial orchards are in bearing. Potatoes and other vegetables seem well adapted to the soil and are grown to some extent. A large percentage of the type has been logged off and can be bought for \$25 to \$50 an acre. Improved areas near the water front command from \$75 to \$100 an acre. Compared with soil conditions of surrounding types it would seem that in many cases higher prices would be justified.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Everett silt loam:

Mechanical analyses of Everett silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25225.....	Soil.....	0.0	1.2	1.1	5.1	15.2	64.5	12.9
25226.....	Subsoil.....	.0	.5	.6	4.6	8.6	74.1	11.1

CLALLAM SERIES.

The soils of the Clallam series are distinguished from those of the Everett series by the prevailingly finer texture and lighter color. The subsoil material is also of finer texture and of more compact structure.

The soils are of gray color, sometimes grading to light grayish-brown, and are predominantly of fine texture, consisting mainly of fine sand, silt, and silty clay. The subsoils consist mainly of compact silty loams or silty clay loams and are generally of slightly lighter color than the surface material. More or less fine gravel and a considerable quantity of iron pellets occur in all the soils of this series.

The soils of this series occupy rolling to hilly uplands and comparatively level plateau remnants. They seem to be derived from both ice laid and water laid material of the glacial drift and occur principally around the base of the Olympic Mountains, the material probably being derived from this source.

CLALLAM GRAVELLY FINE SANDY LOAM.

The soil of the Clallam gravelly fine sandy loam consists of 8 to 10 inches of gray fine sandy loam, containing a relatively large quantity of fine glacial gravel, mixed with many reddish-brown iron pellets about the size of a pea. The subsoil is a lighter colored silty fine sandy loam. When dry it is almost white. As a rule glacial gravel and iron pellets are present in both the soil and subsoil, but in places the content of gravel is almost negligible, in which case the small iron pellets are always abundant. Such an area occurs near the foothills along the National Forest line to the south and west of Port Angeles. This body, as well as that in the vicinity of Port Townsend, contains considerable silt and is somewhat heavier than the Clallam fine sandy loam and decidedly lighter in color.

This type of soil owes its formation to the weathering of compact beds of glacial drift. In a few cases along the foothills of the Olympic Mountains small areas included with this type have been modified by the admixture of material brought down from the hills. In such cases the color may be either gray or purplish-red and the subsoil is always heavier in texture, frequently approaching a clay loam or clay. These areas, however, are of small importance, as their rough topography unfits them for agriculture.

This type of soil is one of the most common found in Clallam County. The largest continuous body, beginning near Sequim, extends westward with irregular outline for nearly 30 miles and over a portion of this strip extends from the mountains to the Strait. Another large body occurs on each side of Washington Harbor from its eastward extension into Jefferson County to Port Discovery. A third body is found on the east side of this bay from Tuckeys to Fairmount.

The Clallam gravelly fine sandy loam has a varied topography, ranging from fairly level in the upland flats or plateaus, as near the coast in the vicinity of Port Angeles, to hilly or broken. The roughest area is that found along the southern boundary of the survey, which is near the foothills of the Olympic Mountains. The areas adjoining Washington Harbor and Port Discovery are also rather rough. The drainage of the type is usually thorough and on the rougher areas it is apt to be excessive.

The forest growth consists chiefly of fir, hemlock, and spruce, with some cedar.

Only a very small percentage of the Clallam gravelly fine sandy loam is under cultivation. Much of it is logged-off land, though considerable areas of virgin forest are still found. The crops are chiefly those used in the dairy business, such as clover, grasses, and

oats cut for hay. Potatoes are grown for home use, and small quantities of fruit are sold in local markets. The soil is easily worked and holds moisture well if properly cultivated. The crops on the few areas under cultivation indicate that the type is well adapted to nearly all the products of the region, especially hay, fruits, and vegetables.

CLALLAM FINE SANDY LOAM.

The soil of Clallam fine sandy loam consists of 12 inches of gray fine sandy loam of loose structure. The surface, to a depth of 2 to 3 inches, contains considerable organic matter, which gives it a darker color and more loamy texture than is found at a lower depth. The subsoil is a gray, slightly mottled fine sandy loam, containing a high percentage of clay and silt, resting at 26 inches on yellowish-gray silty clay loam, with numerous reddish-brown iron stains. A small quantity of iron pellets and fine, glacial gravel is sometimes found in the surface soil, but the presence of the latter is unusual. Near Port Townsend, in Jefferson County, the proportion of silt and clay in the lower subsoil is not nearly so great, the texture of the material being a compact fine sandy loam from the surface to a depth of many feet. The type is loose and easily handled, and allows cultivation under a wide range of moisture conditions.

The Clallam fine sandy loam is derived from ice-laid and water-laid material, consisting chiefly of fine sand and silt.

Only two bodies of this type large enough to map were found in the survey. A number of smaller areas occur scattered through the Clallam very fine sandy loam and Clallam gravelly fine sandy loam in eastern Clallam County. One of the areas mapped includes about a section of land bordering the shore of the Sound at Port Williams. The other is found at Port Townsend, where it approaches in character the soils of the Everett series. Near Port Williams the type occupies a plateau-like eminence which rises abruptly from 50 to 100 feet above the waters of the Sound. Once this elevation is gained, the surface is fairly level, though all of the type has sufficient slope to insure excellent surface drainage. At Port Townsend the type is somewhat more rolling, though none of it is too broken for cultivation.

The type supports a growth of fir, pine, hemlock, and spruce, and a dense covering of salal. Though the type is well adapted to farming, very little of it has been cleared and placed in cultivation. Truck and fruit as well as hay and small grains could be grown successfully. It is well suited to the production of blackberries, dewberries, and strawberries. So far no effort has been made to grow them commercially. The location of the type is excellent as regards markets and shipping facilities.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Clallam fine sandy loam:

Mechanical analyses of Clallam fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25190.....	Soil.....	1.20	5.1	11.9	35.5	8.1	29.8	8.4
25191.....	Subsoil.....	1.0	3.0	7.2	29.8	13.3	32.6	12.8

CHALLAM VERY FINE SANDY LOAM.

The soil of the Clallam very fine sandy loam consists of 12 to 20 inches of gray to light-brown very fine sandy loam, with an average depth of about 15 inches. The subsoil varies from gray very fine sandy loam of somewhat heavier texture than the soil to gray silty clay loam or silty clay. Yellowish-brown iron stains are of common occurrence below the second foot, giving the subsoil at times a decidedly mottled appearance. A number of areas are found where the soil is sticky and adhesive when wet, in which condition the material closely resembles a light silty loam. Such bodies occur on the plateau-like eminence at Port Angeles, west of Port Williams, and in the vicinity of Dungeness.

The soil is derived from compact material of the glacial drift, probably mainly water deposited. The material consists mainly of a mass of fine sands and silt and are underlain by glacial sands and gravels.

Several bodies of Clallam very fine sandy loam are found in Clallam County. The most important of these are in the vicinity of Port Williams, Port Angeles, and about 2 miles west of Dungeness. Two other areas occur on the benchlike elevation just south of Sequim. A phase of the type is also found on Orcas Island, in San Juan County. This body contains a somewhat higher percentage of silt than is usually found in the type. A small quantity of gravel and a few glacial boulders are also found in the soil.

The topography of the Clallam very fine sandy loam is that of level to gently rolling flats or plateaus. Altitudes vary from 25 to 75 feet above the prairie at Sequim and from 50 to 100 feet above the waters of the Sound. The surface of the area near Dungeness is somewhat more rolling than the others. This is caused partly by the natural morainic topography and partly by many deep stream channels. The drainage as a whole is fairly good, though the bodies near Port Williams would be much improved by underdrainage. This need is becoming more and more a necessity as the surplus waters from the irrigated fields saturate more thoroughly the subsoil of these areas.

Excepting the two small areas in the vicinity of Port Williams, almost none of the type is under cultivation. The native vegetation consists mainly of fir, but there is some hemlock, pine, and spruce, as well as a considerable stand of cedar, on the poorer drained areas. Properly handled this soil should be a productive and valuable type. It has a high water-holding capacity, is well drained, level, and easily cultivated. On the areas at present cultivated the crops are oats, clover, peas, and vegetables. The yield of oats ranges from 50 to 80 bushels per acre, but the crop is generally cut for hay and used as feed for dairy stock. Clover yields two cuttings per season, each giving from 1 to 2 tons per acre. Potatoes do well, yielding from 150 to 250 bushels per acre. The soil is well adapted to fruit, especially apples, plums, and berries, though only a small acreage as yet is being devoted to these crops. In the vicinity of Port Williams, Dungeness, and Sequim much of the type lies favorably for irrigation. When thus improved and properly drained the soil should be an excellent one for alfalfa, as well as all of the crops now being grown in the area.

CLALLAM SILT LOAM.

The soil of the Clallam silt loam, to an average depth of 10 inches, consists of a gray to drab silt loam which sometimes contains a small amount of sand and fine gravel. The subsoil, to a depth of 36 inches, consists of a gray, compact silt loam or silty clay loam. A few small glacial boulders are found in both soil and subsoil.

The larger area of this type occurs on Whidbey Island, southeast of Coupeville. Other smaller areas occur in other parts of Island County. The type occupies comparatively level to gently rolling benches that occur near the base of gently rolling uplands where they drop into the shallow basins occupied by the sedimentary soils, such as the Bellingham silt loam.

The natural drainage on the whole is good, but underdrainage would be beneficial in the more level areas. This would in a measure overcome the tendency of the soil to break into clods and to become hard and baked when dry.

The parent glacial material consists mainly of silty clay and fine sand.

A small area of this type of soil is found in the present survey. None of it is under cultivation. Some of the partly cleared land has been seeded to grass and used as pasture, with good results. With proper management to supply organic matter and to improve the physical condition of the soil the land would prove well adapted to farming. It would produce profitable yields of the general farm crops.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Clallam silt loam:

Mechanical analyses of Clallam silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25194.....	Soil.....	4.8	7.4	4.0	3.4	6.0	61.7	12.9
25195.....	Subsoil.....	3.6	10.8	10.1	5.0	4.2	48.2	18.1

MISCELLANEOUS SOILS.

WHATCOM SILT LOAM.

The surface soil of the Whatcom silt loam is distinguished from that of the Clallam and Everett types by the prevailingly deeper reddish-brown tint. It consists of a light-brown to reddish-brown silt loam with an average depth of about 12 inches. A few small, rounded iron concretions are present in the soil, but with this exception the surface material is comparatively free from coarse particles, such as sand or gravel. The subsoil is also more compact and finer than the Everett subsoil and is generally darker than the Clallam subsoil. It consists of a compact, heavy loam or silty loam of a gray to drab color, and also comparatively free from gravel or small boulders.

The principal area of this soil occurs in the gently rolling upland section of San Juan Island, but the type covers only a very small acreage in the area surveyed.

Rolling to gently rolling topography is characteristic of this soil, though the hills are low and rounded and never steep or eroded. When cleared of stumps and underbrush, this soil can be cultivated with more certainty of profitable yields than the greater proportion of the glacial upland types, as its heavy, compact subsoil enables it to maintain the proper moisture supply. It does this by preventing the excessive natural drainage so common on the types underlain by coarser-textured subsoil.

The Whatcom silt loam is derived from the weathering of glacial drift material, probably modified by reworking in glacial waters. It consists mainly of compact deposits of silt, clay, and fine sand, with a very small proportion of coarser material.

A large percentage of the area embraced by this soil is under cultivation. It produces profitable yields of potatoes, truck, fruits, and small fruits. It is also well adapted to the growing of clover and other hay crops, but owing to the fact that the cost of clearing the land is high it is utilized chiefly for crops better suited to intensive farming.

The average results of mechanical analyses of the soil and subsoil, and a single analysis of the lower subsoil of the Whatcom silt loam are given in the following table:

Mechanical analyses of Whatcom silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
16976, 14095, 14099.	Soil.....	1.1	4.5	2.7	7.1	7.3	61.2	15.2
16977, 14096, 14098.	Subsoil.....	.8	3.6	2.7	9.1	10.0	52.0	21.9
16978.....	Lower subsoil.	1.5	5.4	4.1	15.6	10.3	48.5	14.7

SAN JUAN COARSE SANDY LOAM.

The soil of the San Juan coarse sandy loam to an average depth of 15 to 20 inches consists of a dark-brown to black sandy loam, which contains a large proportion of decomposed organic matter. A considerable amount of coarse sand and fine gravel frequently occurs in the surface soil, but the large organic content gives as a whole a fine loamy texture. Glacial boulders of various sizes often occur scattered over the surface, especially near the summits of some of the rounded knolls or ridges. The subsoil is coarser in texture and contains much less organic matter than the surface soil. It consists of gravel and small rounded boulders embedded in a deposit of light-brown to gray loamy sand of medium to coarse texture.

An important area of this soil occupies a small treeless prairie in the southern part of San Juan Island. Other areas of very small extent occur in other sections of San Juan County. A rolling topography and the porous character of the soil and subsoil result in excessive drainage.

The San Juan coarse sandy loam is derived from deposits consisting mainly of sand and gravel probably deposited as glacial drift and possibly modified by water action.

Only a very limited acreage of the type is at present under cultivation. No timber growth occurs on any of the areas occupied by this type. It supports a very fair growth of native grasses and is utilized principally as pasture.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the San Juan coarse sandy loam:

Mechanical analyses of San Juan coarse sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25236.....	Soil.....	30.0	28.0	10.0	3.3	2.7	13.8	12.0
25237.....	Subsoil.....	5.2	35.6	30.4	11.1	2.5	9.3	5.9

TOWNSEND GRAVELLY SANDY LOAM.

The Townsend gravelly sandy loam consists of from 10 to 12 inches of black sandy loam of medium to fine texture, with so high a content of organic matter as to give it the appearance of a loam. The subsoil, to an average depth of 3 feet, is a black fine sandy loam, or sandy loam slightly more sandy than the soil and containing somewhat less organic matter. At from 2 to 4 feet below the surface the material changes abruptly into light-colored, compact gravelly sandy loam, locally known as "cement." When dry the subsoil may be broken down into a white, powdery material, but in its original position or when saturated with water it is impervious and very dense. Both the black soil and subsoil are mixed with stones and small glacial gravel, though to a smaller extent than the deeper light-colored material. The type has the general appearance of the corresponding member of the Spanaway series, but differs from it in having a more compact subsoil.

The type is made up of glacial drift probably modified by the action of glacial waters. A later modification by conditions of restricted drainage is also indicated by the high content of organic matter. At some later time drainage was very much improved either by the elevation of the type or by the erosion of the valley bordering it on the east.

Only one small body of Townsend gravelly sandy loam occurs in the area. This lies on the high bluff at Port Townsend, the black surface soil gradually getting more shallow as the distance from the Sound increases. In its original condition it supported a scattering growth of fir, pine, and oak, a part of it being covered only by native grasses.

The whole area of the type is embraced by the city of Port Townsend and is, therefore, of little agricultural importance.

Results of mechanical analyses of samples of the soil and subsoil of this type are given below:

Mechanical analyses of Townsend gravelly sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25276.....	Soil.....	2.7	13.7	13.1	23.7	11.1	19.3	15.7
25277.....	Subsoil.....	2.9	14.5	16.1	24.4	8.7	22.7	10.5

SOILS DERIVED FROM GLACIAL OUTWASH MATERIAL EXCLUSIVELY.

SPANAWAY SERIES.

The soils of the Spanaway series are characterized by dark-colored surface material and light-colored porous sandy and gravelly sub-

soils. They are confined to the sparsely forested or treeless areas locally known as "prairies" in the glaciated upland districts. The soils are derived from deposits of coarse glacial outwash gravel with very little interstitial fine material and a shallow veneer of sand and fine gravel and from deep deposits of sand carrying little or no gravel. These deposits represent material left by the swift waters of subglacial streams, under the partly submerged or floating ice front, and material which was laid down as glacial outwash by the water from the melting ice. The areas occupied by these soils have the general appearance of level plains, but small mounds, shallow intervening basins, and low, flat-topped terraces give them as a whole an undulating to gently rolling topography. The larger "prairies" are traversed by narrow ridges, which often rise 20 to 40 feet above the level of the surrounding plain. These ridges are covered by deposits of glacial drift and support a heavy growth of timber, while the gravelly prairies are treeless or support only a very stunted tree growth.

The coarse gravelly type of this series is excessively drained and is of low agricultural value. The loamy sand and loamy fine sand soils are also excessively drained, but can be profitably cultivated.

SPANAWAY LOAMY SAND.

The Spanaway loamy sand consists of 24 to 36 inches of a black, medium-textured loamy sand underlain to a depth of several feet by a light-brown to gray medium-textured sand. Like the other soils of this series, the dark color and loamy appearance of the surface soil are chiefly due to the presence of a high percentage of fine particles of humus. At times small amounts of gravel are found in both soil and subsoil, while small areas of a rather coarse sandy loam are not uncommon. As the type has a loose, incoherent structure and is well drained, it may be easily cultivated under a wide range of moisture conditions.

The Spanaway loamy sand is derived from extensive deposits of sandy material laid down by glacial waters. The original characteristics of the surface soil have been modified to a considerable extent by large accumulations of organic matter.

Five bodies of Spanaway loamy sand are found in the area. All of these occur in the eastern part of Thurston County, the largest body, which embraces approximately 4 square miles, being located just south of Pattisons Lake. Other important bodies are found south of Long Lake and southeast of Lake St. Clair.

The Spanaway loamy sand has a comparatively level topography, although the low ridges, mounds, and shallow depressions give the type as a whole a slightly rolling appearance. Because of the very porous structure of both soil and subsoil crops grown on this type are

liable to be injured, suffer from deficiency in the supply of moisture, although fairly good results are secured where intensive methods of cultivation are employed. Owing to the greater percentage of fine material in the subsoil the crops do not succumb as readily to drought as on the more porous gravelly sandy loam of this series.

The Spanaway loamy sand is a prairie soil and is practically treeless. There are, however, on the outer borders a few firs, pines, and oaks, which represent encroachments from adjoining forested areas of other types of soil. The uncultivated areas are covered with brakes and a variety of grasses.

At present a large part of the type is under cultivation, the remainder being used for grazing. The leading crops are hay, oats, rye, barley, and wheat. Oats yield from 30 to 60 bushels per acre, wheat 16 to 30 bushels per acre, barley 20 to 25 bushels per acre, and hay 1 to $1\frac{1}{2}$ tons per acre. In most cases these yields could be increased by more intensive methods of cultivation. Where a supply of water for irrigation purposes is available, this soil should be well adapted to a wide range of crops, and especially to strawberries, truck crops, and potatoes.

Land of this type ranges in value from \$15 to \$150 an acre, depending on location and improvements.

The average results of mechanical analyses of samples of the soil and the results of a single analysis of the subsoil are given in the following table:

Mechanical analyses of Spanaway loamy sand.

Number.	Description.	Fine	Coarse	Medium	Fine	Very fine	Silt.	Clay.
		gravel.	sand.	sand.	sand.	sand.	Per cent.	Per cent.
25269, 25271.....	Soil.....	2.4	24.3	24.0	20.9	9.2	9.7	9.2
25270.....	Subsoil.....	2.9	30.3	26.7	17.8	7.9	7.8	6.7

SPANAWAY LOAMY FINE SAND.

The soil of the Spanaway loamy fine sand consists of 3 to 5 feet, or even more, of black loamy fine sand resting upon a light-brown to gray fine sand, which extends to a depth of many feet. Mechanical analysis shows the type to contain very small quantities of silt and clay, the loamy appearance, as well as the dark color, being chiefly due to the presence of a high percentage of fine particles of vegetable matter. Like all other soils of this series, the Spanaway loamy fine sand has a loose incoherent structure, and as drainage is very free the type may be cultivated almost immediately after heavy rains.

The Spanaway loamy fine sand has been derived from deposits of fine sand laid down by glacial waters. The character of the surface

material has been influenced to a considerable degree by accumulations of humus from the growth and decay of a variety of grasses and ferns.

Several areas ranging in extent from one-fourth square mile to several square miles have been mapped in Thurston County. The two largest and most important bodies occur, respectively, about 2 miles south and $3\frac{1}{2}$ miles southeast of Tumwater. Other bodies are located in the vicinity of Mima, Lacey, and Plumb.

The topography of the Spanaway loamy fine sand is comparatively level, although slightly diversified by low ridges, gentle swells, and shallow depressions. As both soil and subsoil are quite porous, the drainage is inclined to be excessive, although good results can be secured where intensive methods of cultivation are followed, crops being less readily affected by drought than on the coarser textured loamy sand and gravelly sandy loam.

Like all other soils of this series, the areas occupied by the Spanaway loamy fine sand are commonly known as "prairies," and are largely treeless. Occasional small groups of pine, fir, and oak are found, and the outer margins support a fair stand of fir, where forests on contiguous soils have encroached upon the prairie areas. The treeless areas are covered with brakes and a variety of grasses, which furnish a fair amount of pasturage. Where an adequate supply of water for irrigation can be obtained, the type should be well adapted to strawberries, potatoes, truck and general farm crops. At present it is devoted to the production of hay, barley, oats, wheat, and some fruit. The yields of hay are 1 to $1\frac{1}{2}$ tons; oats, 30 to 60 bushels; wheat, 18 to 30 bushels; and barley, 20 to 25 bushels per acre. Strawberries and small fruits do fairly well when given constant cultivation, but tree fruits are not as successfully grown. It is quite probable that all these crops could be improved by taking greater precautions to conserve the soil moisture.

Areas of Spanaway loamy fine sand can be purchased for \$25 to \$150 an acre, depending on location and improvements.

The following table gives the average results of mechanical analyses of samples of the soil of this type:

Mechanical analyses of Spanaway loamy fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
23687, 25272.....	Soil.....	0.2	1.3	9.6	55.7	13.1	12.5	7.5

SPANAWAY GRAVELLY SANDY LOAM.

Where typically developed the soil of the Spanaway gravelly sandy loam consists of 10 to 18 inches, with an average of 12 inches, of a

black medium to coarse textured sandy loam carrying considerable quantities of gravel, rounded glacial cobbles, and boulders, while at times many of these rocks are found strewn over the surface. The black color is due to the large amount of organic matter, which is always present, giving the type characteristics of a more loamy soil.

The subsoil consists chiefly of rounded, waterworn rocks of all sizes up to 8 or 10 inches in diameter. While there are small quantities of coarse sand and fine gravel in the subsoil the type as a whole is characterized by a relatively low percentage of fine interstitial material below the surface 18 inches.

A phase of the Spanaway gravelly sandy loam occurs in what are known as the mound prairies, the most important of which are west of Tenino, south of Little Rock, and near Plumb, in Thurston County. In these localities the mass of rounded cobble and gravel forming the subsoil seems to lie practically horizontal, the mounds being made up of the material which forms the surface soil. This causes the depth of the soil to vary considerably, often being 2 or 3 feet deep in the mounds while it is only a few inches deep in the intervening depressions. In such areas there is frequently more sand and fine gravel in the subsoil, the material often being distinctly stratified.

Another phase occurs along stream courses and in basins, where the soil is of a much finer texture—either a fine sandy loam or silty loam, with very small amounts of gravel. These areas are too small to be indicated in a map of this character. Except on the mound prairies and in a few instances where the underlying cobbles and gravels lie so near the surface as to interfere with the plow, the type lends itself readily to the use of all kinds of improved farm machinery.

The fact that areas of the Spanaway gravelly sandy loam are found along the broader valleys which served as an outlet for glacial streams, and along the valleys some distance from the boundary of glaciation, would seem to indicate that the deposits of sand, gravel, and small boulders from which this soil is derived were laid down as glacial outwash. The absence of fine material in the subsoil is probably due to the fact that it was carried away by swift waters or glacial floods at the time of deposition. The character of the surface material was later modified by the accumulation of large quantities of decomposing vegetation.

The most extensive bodies of Spanaway gravelly sandy loam occur in Thurston County in the vicinity of Yelm, Tenino, Rochester, and Rainier, where areas many square miles in extent are found. Numerous other bodies of varying size occur in the central, eastern, and southwestern portions of this same county. Besides those already mentioned there are several smaller areas in various parts of Mason

County and along the Chehalis River Valley in the vicinity of Elma, Oakville, Loraine, Satsop, and Cedarville, in Chehalis County.

The Spanaway gravelly sandy loam occupies broad, level to gently rolling upland plains having the characteristic glacial topography. The most striking features are the more or less extensive terraces forming flat-topped embankments 10 to 20 feet high, and the low rounded mounds 1 to 3 feet high and 10 to 30 feet in diameter. On account of the coarse and porous nature of the subsoil the drainage of the type is excessive and as a result constant and thorough cultivation is required to grow crops with any certainty of success.

By far the greater proportion of the Spanaway gravelly sandy loam is either treeless or else supports only a sparse and stunted growth of fir, pine, and oak. There are, however, some small forested tracts, which furnish good piling and tie timber. The treeless areas support a variety of grasses and brakes.

Only a very limited area of the type is at present utilized for crop production, the greater proportion being used for grazing. Small areas along stream courses and other areas where the surface soil is unusually deep produce fair yields of hay, oats, and wheat. In such places oats yield 20 to 40 bushels per acre, wheat 12 to 18 bushels per acre, and hay one-half to 1 ton per acre. Where a sufficient amount of water is available there is a possibility of the more level areas being developed under irrigation.

Land of this type ranges in value from \$5 to \$57 an acre, depending on location and improvements.

The following table gives the average results of mechanical analyses of typical fine-earth samples of the soil:

Mechanical analyses of Spanaway gravelly sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
22067, 22069.....	Soil.....	Per cent. 10.9	Per cent. 20.2	Per cent. 7.1	Per cent. 9.5	Per cent. 7.3	Per cent. 26.0	Per cent. 18.9

SOILS OF THE GLACIAL LAKE BASINS.

MISCELLANEOUS TYPES.

BELLINGHAM SILT LOAM.

The soil of the Bellingham silt loam consists of a dark-brown to black silt loam which contains a variable quantity of decomposed organic matter. In some areas a very shallow deposit of organic matter overlies the silty soil, causing the surface to have a very dark brown to black appearance, but in other areas, especially where the land has been cultivated, the organic matter has become

mixed with the silty soil and the surface has a dark-gray or drab color. The subsoil consists of a heavy, compact drab-colored silt loam, which becomes slightly heavier in texture as the depth increases, until at an average depth of 36 inches it has the characteristics of a silty clay or silty clay loam. Deposits of diatomaceous earth are sometimes found at a shallow depth below the surface, and pockets or strata of sand or gravel are frequently encountered in the subsoil.

The Bellingham silt loam occupies the majority of the shallow upland basins occurring at intervals throughout the glaciated region of the area surveyed. Many of these basins are almost wholly surrounded by rolling hills and ridges, and the drainage water from the adjacent uplands keeps them in a wet, poorly drained condition during the winter months. The natural drainage is very poor, and many of the smaller depressions have no outlet for the water which collects in them during the rainy season.

In some of the smaller basins the texture of the soil varies from that of the typical Bellingham silt loam. This is due to the fact that the texture of the soil occupying the shallow basins is influenced by the character of the material washed down at times of heavy rainfall from the adjacent uplands. In some localities the depressions are surrounded by areas of light, sandy upland soil, and the soil contains a high percentage of sand, while other areas occur that are surrounded by the more silty upland soils and contain a higher percentage of silt and clay than the typical Bellingham silt loam. These local phases are not of sufficient importance to be separated into distinct types in a reconnaissance survey, as they are similar to the typical soil in agricultural value, drainage conditions, and origin.

The soil is derived from material washed down from the uplands and deposited in these shallow basins and depressions during the period when they were covered by the waters of shallow lakes or ponds or were in a wet, swampy condition. The large content of organic matter found in the soil owes its origin to the decay of the rank growth of swampy vegetation found in such places.

Inherently the soil is productive, and when well drained it is well adapted to farming. Surface ditches are generally used in draining this land, but tile drainage has been used to some extent and has proved the more satisfactory. When well drained and thoroughly cultivated the soil produces very profitable yields of all crops grown in the area. Irish potatoes do well, yielding from 150 to 300 bushels per acre. When the soil is thoroughly drained and cultivated, even larger yields are often secured. The soil is well adapted to both clover and timothy, the yield of hay being estimated at 3 to 4 tons per acre. Many varieties of vegetables are grown on this soil for the local markets. The yields are very profitable. Oats are grown to

a limited extent; and large yields are always secured. Plate III, figure 3, shows a wheat field on this type.

The value of this land varies from \$25 to \$300 an acre, depending on its location in the area and the extent to which it has been improved.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Bellingham silt loam:

Mechanical analyses of Bellingham silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
17725,17727	Soil.....	0.3	1.3	0.4	2.8	8.3	68.7	18.1
17726,17728	Subsoil.....	.2	.7	.5	4.1	8.5	72.1	13.9

EBEYS SANDY LOAM.

The surface soil of the Ebey sandy loam consists of 8 to 15 inches of black sandy loam of medium to fine texture and containing a very large quantity of organic matter. The subsoil, to a depth of 36 inches, is a gray light sandy loam or loamy sand, the sand content varying in texture from medium to fine.

A gravelly phase of this soil occupies the northern part of a small prairie on Whidbey Island, locally known as Smiths prairie. Here the soil contains a considerable quantity of gravel in both soil and subsoil, and the soil is of lower agricultural value than the greater proportion of the type. This gravelly phase has been indicated on the soil map by means of a symbol. The two larger areas of this type are located in Ebey's and Smiths prairies, on Whidbey Island, but smaller areas occur in various other localities in Island County.

The topography is level to gently rolling, and the type as a whole has good natural drainage.

The soil is probably derived mainly from glacial material of adjacent slopes which has been reworked, eroded, and redeposited by water, but in shallower water and at a higher elevation than the finer sediments of the Bellingham silt loam, which often occupies lower depressions adjoining areas of this soil. The areas occupied by the Ebey sandy loam were probably at one time covered by the waters of small glacial lakes, sloughs, or served as broad glacial channels, emptying into the heads of small bays or inlets.

The large organic content is due to the decay of the vegetation flourishing under conditions of poor drainage. The gravelly phase seems to have been formed by the accumulation of organic matter over low-lying deposits of coarser glacial material, with a minimum wash of local materials.

When well cultivated the Ebey sandy loam, which is very productive, gives good yields of all crops grown. The principal crop is Irish potatoes, of which the yield ranges from 40 to 300 bushels per acre. Wheat and oats are grown to a limited extent and produce large yields. The oats grown are of excellent quality, but the wheat is too soft for milling purposes. Onions, carrots, sugar beets, small fruits, and vegetables are grown to a limited extent and do exceedingly well.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Ebey sandy loam:

Mechanical analyses of Ebey sandy loam.

Number.	Description.	Fine	Coarse	Medium	Fine	Very fine	Silt.	Clay.
		gravel.	sand.	sand.	sand.	sand.	Per cent.	Per cent.
25209.....	Soil.....	0.4	11.1	29.2	16.0	9.9	21.6	11.3
25210.....	Subsoil.....	.4	14.8	43.2	20.5	3.3	12.9	4.8

SOILS DERIVED FROM OLD SEDIMENTARY DEPOSITS.

MISCELLANEOUS TYPES.

HOQUIAM CLAY LOAM.

The Hoquiam clay loam consists of a reddish-brown to red clay loam or silty clay loam having an average depth of 12 to 15 inches. It rests upon a reddish-brown to red clay loam subsoil which is underlain at a depth of 3 to 10 feet by a compact mass of loosely cemented sandstone, basalt, and quartz gravels. These gravels consist mainly of waterworn fragments of soft, impure sandstones, which are usually coated with a reddish stain of iron oxide, but frequently with carbon or manganese oxide. Occasionally the gravelly substratum is absent, the subsoil extending to a depth of many feet with little or no change. Strata of impure sandstone are frequently found embedded in or overlying the gravels, but they are seldom extensive. Usually the mass of gravels, conglomerates, and sandstones lie unconformably upon the tilted sandstones and shales that have entered into the composition of the Melbourne silty clay loam. Small amounts of gravel are found in both soil and subsoil, the percentage being greater where the gravelly substratum lies near the surface.

A phase of this type occurs along the Hoquiam and Wishkah Rivers and their main tributaries where there are comparatively level benches often extending for several miles along the streams and having an average width of one-half to 1 mile. On these benches the soil is usually darker in color and frequently carries more gravel,

while the subsoil is somewhat lighter in texture, the underlying gravel beds being nearer the surface. In these areas many small depressions of a dark-brown or black silt loam underlain by a yellow or mottled gray and yellow clay or clay loam are found. Generally speaking the soil is mellow and can be cultivated under a wide range of moisture conditions.

The Hoquiam clay loam is derived through weathering from beds of gravels or conglomerates, clays, and soft arenaceous shales. These deposits probably represent marine sediments that were laid down in shallow waters and elevated during Pleistocene times.

The gravels were chiefly derived from sandstones and shales which were similar to those underlying the Melbourne silty clay loam, and this fact accounts largely for the similarity in color and texture of these types. These sediments are soft, and as a result erosion has been very rapid on the steeper slopes.

With the exception of one small body near South Aberdeen and another southeast of Markham all of the Hoquiam clay loam mapped lies west of the Wynooche River and north of Grays Harbor, where it embraces the greater portion of this part of the survey. The largest continuous body lies between the Wynooche and Humptulips Rivers. Three other bodies, also of considerable extent, occur between the Humptulips River and the Pacific Ocean.

The topography of the type is rolling to hilly, the hills being more rounded and the slopes not quite so steep as those of the Melbourne silty clay loam. It resembles the Copalis clay loam in many respects, but differs from it as a whole in having a much more rolling topography. The northern part of the area which lies between the Hoquiam and Humptulips Rivers is comparatively level, but becomes more hilly in the vicinity of Grays Harbor. Other comparatively level areas occur as benches along the larger streams. Except for the small depressions which occur at intervals in these level areas the type is well drained.

The original forest growth consists of fir, spruce, cedar, and hemlock, the fir being by far the most abundant.

The more level areas of Hoquiam clay loam should be well adapted to all the crops grown in the region, especially to small grains, hay, and clover. Because of the tendency to erosion it is necessary to use a cover crop on the steeper slopes during the rainy season. As such areas furnish very good hay and pasture they are best adapted to dairy purposes. Fruit growing should also prove a profitable industry on portions of this type providing the necessary precautions are used to check erosion.

At present only a few very small areas are under cultivation, the yields being similar to those secured on the more level areas of Melbourne silty clay loam.

A large proportion of the type is still in forests, and on such areas the valuation is based primarily on the character of the timber growth. Logged-off tracts can be purchased for \$10 to \$20 an acre, depending on location.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Hoquiam clay loam:

Mechanical analyses of Hoquiam clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25238, 25240.....	Soil.....	4.1	7.3	4.1	7.3	4.6	40.1	32.6
25239, 25241.....	Subsoil.....	3.6	7.2	4.4	8.5	6.3	39.3	31.2

COPALIS CLAY LOAM.

Where typically developed the Copalis clay loam consists of 12 to 18 inches of a brown to dark-brown heavy clay loam of silty texture usually carrying a high percentage of organic matter. It rests upon a light-brown, yellow, or mottled yellow and gray compact clay which is almost invariably underlain at a depth of 2 to 5 feet by a compact mass of loosely cemented basalt, quartz, sandstone, and shale gravels. These gravels, like those underlying the Hoquiam clay loam, are almost invariably coated with stains of iron oxide, manganese oxide, and carbon. The greater part of them are so soft that they disintegrate readily when exposed to weathering agencies. Small amounts of gravel are found in both soil and subsoil, the proportion being considerable on the small knolls where the gravelly substratum is encountered at comparatively shallow depths.

The type includes a better-drained phase where both soil and subsoil have a reddish color. These areas are similar to the Hoquiam clay loam, except for the darker coloring due to increased organic-matter content and heavier-textured soil. The type apparently does not carry quite as much clay and organic matter as the Montesano clay loam. The soil is level and friable, and when once the land has been cleared cultivation is easy.

The Copalis clay loam is a residual soil, formed by the weathering of partly consolidated clays, sands, and gravels. It occupies marine terraces which were probably elevated during Pleistocene times.

Four bodies of Copalis clay loam have been mapped in the area, all of which occur in the northwestern part of Chehalis County. The largest and most important body embraces the greater portion of that part of the survey between the Humptulips and Chehalis Rivers. The other bodies are of limited extent, and while not typical have been included with this type. Two of them occur along the Wishkah

River just south of Grand Forks and one about 4 miles west of Montesano along the Chehalis River Valley.

The Copalis clay loam occupies table-lands or benches having an elevation of 20 to 50 feet above the stream channels. The topography is level to gently rolling, differing in this respect from both the Montesano clay loam and Hoquiam clay loam, the former being generally flat, while the latter is rolling to hilly. Many small poorly drained depressions occur throughout the type, but the more rolling areas have sufficient slope to insure fairly good surface drainage.

The greater part of the three small bodies of Copalis clay loam previously mentioned have been logged, but the timber on the largest areas is practically untouched. The native vegetation consists of fir, hemlock, spruce, and cedar, with a dense undergrowth of salal. Trees on this soil are often of a smaller size than those on some of the other upland types of the area.

As the Copalis clay loam is fairly level, it can be cultivated with less risk of damage from erosion than the more rolling soils which occupy the greater portion of Chehalis County. The rainfall is somewhat greater here than in many other parts of the area, and the soil is retentive of moisture. The type, therefore, should be an ideal location for dairy farms. It is probably well adapted to hay, grain, and pasture—all requisites for successful dairying.

As yet no attempt has been made to cultivate the soil, but it is thought that certain fruits might be profitably grown on the better drained areas.

The value of forested areas is determined by the character of the timber growth. Logged-off tracts may be purchased for \$10 to \$25 an acre, depending on location.

DALLAS COARSE SANDY LOAM.

The soil of the Dallas coarse sandy loam, to a depth of 12 inches, consists of a dark brown to black sandy loam which contains a large amount of decomposed organic matter. A small quantity of rounded glacial gravel and an occasional glacial boulder are sometimes found embedded in the soil or scattered over the surface. The subsoil from 12 to 36 inches in depth consists of a compact mass of loamy sand or light sandy loam and small gravel.

This type of soil occurs in San Juan County and is of very limited extent. It occupies narrow benches or small plateaus lying at the base of some of the higher hills and ridges where extensive areas of the underlying rock outcrop along the steeper slopes.

The soil is derived principally from material which owes its origin to the disintegration of the hard metamorphosed sandstones which outcrop along the steeper hillsides, but the presence of glacial gravel

and boulders in the soil shows that the material forming this type and especially that forming the subsoil is partially of glacial origin.

In some areas the soil has only a shallow depth and the underlying rock formations are encountered at from 3 to 5 feet below the surface. The small benches and plateaus occupied by this type have an almost level topography, and the type as a whole is well adapted to agricultural purposes. The limited acreage under cultivation produces very profitable yields of small fruits, potatoes, and vegetables. The small orchards located on this type do exceedingly well, and the soil seems well adapted to the growing of fruits.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Dallas coarse sandy loam:

Mechanical analyses of Dallas coarse sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25201.....	Soil.....	13.6	33.6	14.9	5.1	1.5	19.1	12.2
25202.....	Subsoil.....	8.6	39.4	22.0	5.1	1.6	11.7	11.6

MONTESANO SERIES.

Topographically the members of the Montesano series occur in two positions, one as benches along streams and the other as depressions in more rolling areas of other soils. They owe their origin to the weathering of a compact or partly consolidated mass of sands, clays, and stream and beach gravels which were probably elevated during Pleistocene times. The gravels consist chiefly of rounded impure sandstones, although a considerable amount of basalt, shale, and quartz gravels also occur. The original characteristics of the soil have been influenced to a considerable extent by large accumulations of organic matter.

The Montesano soils are distinguished from the Copalis and Hoquiam soils by the darker color of the surface material.

Owing to the impervious nature of the subsoil and flat topography the natural drainage is apt to be deficient, though the two bodies, one at Montesano and one at Humptulips, are well drained.

MONTESANO CLAY LOAM.

The Montesano clay loam, to an average depth of 16 to 24 inches, consists of a black clay loam or silty loam carrying a high percentage of organic matter. It is usually underlain by a compact clay loam or sandy clay loam which is subject to considerable variation in color. In the poorly drained areas, notably in the vicinity of Axford, the subsoil is a gray clay mottled with yellowish-brown

iron stains, while in the larger and more typical areas it is a reddish-brown to yellowish-brown clay loam mottled with gray. This material always rests upon a compact mass of loosely cemented sand and gravel at a depth of $2\frac{1}{2}$ to 5 feet. Embedded in this material are occasional pockets of loose incoherent gravels and sands.

Small amounts of gravel are frequently found in both soil and subsoil, the percentage being considerably higher in the latter. In the vicinity of Humptulips both soil and subsoil contain comparatively large amounts of gravel, while the substratum is coarser textured and more porous. Some of the smaller bodies near Axford are quite free from gravel. The soil is mellow, and except in a few instances where the drainage has been retarded may be easily cultivated under a wide range of moisture conditions.

The Montesano clay loam is a residual soil and owes its origin to the weathering of the compact mass of sand, clay, and beach gravels which were probably elevated during Pleistocene times. The gravels, which are similar to those underlying the Hoquiam clay loam, consist of rounded impure sandstones, mixed with basalt, shale, and quartz. The original characteristics of the soil have been modified to a considerable extent by large accumulations of organic matter, which has probably resulted from restricted drainage conditions.

Several bodies of Montesano clay loam have been mapped, all of which occur in Chehalis County, being confined to that part of the area which lies north of the Chehalis and west of the Satsop Rivers. The largest bodies are found at Humptulips and Montesano. Several smaller bodies occur in the vicinity of Axford and Anderson.

Topographically the Montesano clay loam occupies two distinct positions, one as benches along streams and the other as depressions in the more rolling areas of Hoquiam clay loam. Except for the body near Montesano, which becomes quite rolling in the western portion, the type is generally level. Where it occurs as bench lands there is nearly always sufficient slope from the uplands toward the stream valleys to insure good surface drainage. Some of the flat areas would be improved by artificial drainage, as they frequently receive from the surrounding uplands the surplus waters, which are retarded in their downward movement by the compact nature of the subsoil.

This type, which is commonly known as "prairie land," supports only a scattering tree growth consisting of fir and pine. The small poorly drained depressions are frequently covered with small alder, cedar, willow, and poplar, in addition to the pine and fir, while brakes are numerous on all of the type.

Except for the two bodies at Montesano and Humptulips no attempt has been made to cultivate the type. The principal crops grown are oats, wheat, hay, potatoes, and some fruit. Oats yield 45 to 75 bushels per acre, wheat 25 to 40 bushels, and hay $1\frac{1}{2}$ to $2\frac{1}{2}$ tons

per acre. The greater part of the type can be cleared at comparatively small cost, and as it is level and retentive of moisture should be well adapted to general farming and dairying.

The more remote undeveloped areas of Montesano clay loam can be purchased for \$10 to \$15 an acre, while improved farms are held at \$75 to \$150.

Below are given the average results of mechanical analyses of samples of the soil and subsoil of this type:

Mechanical analyses of Montesano clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25244, 25250, 25252....	Soil.....	0.6	3.1	2.5	9.4	7.4	46.6	30.3
25245, 25251, 25253....	Subsoil .	1.4	4.3	4.1	12.6	13.4	44.6	19.5

MONTESANO SILTY CLAY LOAM.

The Montesano silty clay loam consists of 12 to 14 inches of a dark-brown to black silty clay loam or clay loam carrying a high percentage of organic matter. It rests upon a mottled gray, yellow, and brown silty clay loam or silty clay which is underlain at an average depth of 30 inches by a compact mass of sand, gravel, and clay. At times the gravelly substratum is found much nearer the surface and again not encountered within less than 3 feet.

This type includes a mucky phase which occurs in small treeless flats or depressions on both sides of the Chehalis River in western Chehalis County, known locally as prairies. This phase differs from the typical soil in having a much higher organic matter content and darker color and is indicated upon the soil map. The type is easily cultivated under the proper moisture conditions.

The Montesano silty clay loam owes its origin to the decomposition of deposits of sandstone, basalt, and shale gravels, which were elevated during Pleistocene time. The original material has been considerably modified by weathering and the accumulation of much organic matter which has resulted from restricted drainage conditions.

Three bodies of Montesano silty clay loam have been mapped in the area, all of which are found in the northwestern part of Chehalis County. The largest and most important embraces several square miles just east of Moclips. Other smaller bodies occur southeast of Copalis and along the Chehalis River.

The Montesano silty clay loam occupies level to gently rolling benches seldom more than 75 feet above sea level. Drainage over much of the type is rather deficient, owing to the impervious nature of the subsoil and flat topography.

The type is covered with a very dense and tangled growth of salal, small cedars, and an occasional spruce, fir, and pine. Small treeless areas are frequently encountered which are covered with a variety of grasses.

None of the type is under cultivation, the greater part still being timbered. Owing to the dense forest growth and the large amount of fallen timber the type is a very difficult one to clear. When once cleared and properly drained, it should be well adapted to the production of hay, grain, and to dairy farming. The more open tracts at present furnish a fair amount of grazing during the summer months. Logged-off areas of this type can be bought at \$15 to \$25 an acre. The value of the forested tracts is based primarily on the timber growth.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Montesano silty clay loam:

Mechanical analyses of Montesano silty clay loam.

Number.	Description.	Fine	Coarse	Medium	Fine	Very fine	Silt.	Clay.
		gravel.	sand.	sand.	sand.	sand.	Per cent.	Per cent.
25242.....	Soil.....	0.4	2.3	2.3	6.7	4.7	60.1	23.6
25243.....	Subsoil.....	.7	1.2	1.8	7.0	7.2	63.5	18.9

RESIDUAL SOILS OF THE HILLY DISTRICTS.

MELBOURNE SILTY CLAY LOAM.

The Melbourne silty clay loam in its typical development consists of 8 to 15 inches of light brown to brownish-red silty clay loam, sometimes approaching a silt loam, containing at times a considerable amount of soft shale fragments and silty concretions of iron. From the analysis it will be seen that the material contains a high percentage of silt and clay, which is frequently sufficient to render the type sticky and adhesive if plowed when even moderately wet. If worked when dry the material comes up loose and mellow, forming an excellent seed bed.

The subsoil typically developed consists of silty clay loam or clay loam varying in color from yellowish brown through reddish brown to red. As a rule this material extends to a depth of several feet, though in some instances the underlying shales and sandstones are found at from 3 to 5 feet below the surface.

In addition to the type as described several closely related phases were encountered. The most important of these embraces a rather extensive area between the Chehalis and North Rivers in Chehalis County, indicated upon the soil map by symbol. Here the type con-

sists of 12 to 15 inches of a dark-brown to nearly black silty clay loam underlain by a mottled gray, yellow, and brown silty clay loam or clay loam which rests upon soft impure sandstones and shales at a depth of 2 to 8 feet. The chief difference between this body and the typical Melbourne silty clay loam lies in the color, the phase being considerably darker, probably owing to the greater content of organic matter.

North of Macks Spur, in Chehalis County, more or less extensive bodies of a sandy clay loam are included with this type. This difference in texture is due to the fact that here the soil is derived almost entirely from sandstone rather than a mixture of sandstone and shales. In this same section and also between the Wynooche and Satsop Rivers and southeast of Humptulips the slopes are so steep that the soil is either very shallow or has been entirely removed, leaving exposed the massive gray sandstones and shales.

Still another phase of minor importance is found along the Chehalis River southwest of Elma. Here the texture of the soil has been influenced to a certain extent by a mixture of the sand which makes up the underlying strata of the bluffs. Areas are also found in the northeastern part of Chehalis and the western part of Thurston Counties, where the soil is of a somewhat heavier texture and the color a deeper red than is ordinarily the case. Small bodies having a dark-brown surface have also been included with the type.

The Melbourne silty clay loam is a residual soil formed from the decomposition of arenaceous shales and argillaceous sandstones of Tertiary age.

The type is one of the most extensive mapped in the area. It includes practically all of the uplands of Chehalis County lying south of the Chehalis River and the greater portion of the county lying east of the Wynooche. Areas are also found in Thurston County in the vicinity of Tenino, Bordeaux, and Rochester.

The topography of the Melbourne silty clay loam ranges from hilly and broken to comparatively level, the latter areas being limited in extent and found only on the high plateau. A large portion of the type is so rough as to preclude the profitable use of improved farm machinery, though much of it can be utilized for dairy purposes. Erosion of the steep slopes, when placed under cultivation, makes it more desirable to keep such areas in forest.

The original forest growth consists chiefly of fir and small amounts of cedar, spruce, and hemlock. The latter is the most common growth on old burns or where the original growth has been logged off.

The level areas of the Melbourne silty clay loam are adapted to all of the crops grown in the region. Oats, hay, and fruit are of importance in the order named. Oats yield from 35 to 60 bushels per acre, with an average of 45 bushels, hay from 1 to $2\frac{1}{2}$ tons, and

potatoes from 100 to 200 bushels. Larger yields of hay are being secured from well-seeded clover fields under the most favorable conditions. Potatoes are grown chiefly for local consumption.

Many of the more rolling areas are too rough for general farm crops and are better adapted to stock raising and dairy farming.

Values range from \$7.50 to \$100 an acre, depending upon location, topography, and improvements.

RESIDUAL SOILS OF THE ROUGH MOUNTAINOUS DISTRICTS.

MISCELLANEOUS TYPE.

OLYMPIC LOAMS.

The Olympic loams cover a number of extensive areas in the region surveyed and include a variety of soil materials which because of their rough topography and inaccessibility were not shown separately on the accompanying soil map. The chief characteristic of the type is the outcropping of basaltic rock or its presence at a shallow depth. Fragments of the rock are also found scattered through the soil composing at times a high percentage of the bedrock covering. In the Black Hills and in several other localities a hard, fine-grained sandstone is frequently found overlying the basalt, and where so found has been an important factor in the formation of the soil.

Although the soil varies considerably in texture, the greater part of the type mapped consists of from 12 to 15 inches of dark-brown to red, heavy loam or silty clay loam. The subsoil is usually a red-dish-brown to red silty clay loam or clay of compact structure. Both soil and subsoil contain numerous angular fragments of basalt or sandstone rock varying in size from an inch or more to a foot across. Areas are also found, notably along the Strait and Hood Canal and in Mason and Thurston Counties, where residual soil has been mixed with glacial material. Here the soil consists of heavy sandy loam to loam with considerable amounts of small, rounded gravel.

The type has three distinct sources of origin: The weathering of the Tertiary basaltic rocks, which form the chief underlying material of the hills; the weathering of the Tertiary sandstone, which, in a number of instances, overlies the basaltic rock; and the intermingling of these materials and the glacial sands and gravels of which the Everett soils are formed.

The type is one of the most extensive mapped in the area, as it includes the greater part of the rough, mountainous districts. The largest body is found in the western part of the area, where for 25 miles it includes the principal part of the region between the mountains and the Strait. It also occurs along Hood Canal in both Jefferson and Mason Counties, in the western and southeastern

part of Thurston County, and in the northeast part of Chehalis County.

The topography of the type is rough and mountainous, and the drainage is excessive. Scattered through this mountainous region are small areas of comparatively level land, in which the soil consists of red to reddish-brown heavy loam from 2 to 4 feet deep. These areas are usually fairly well drained and are very productive.

The native vegetation on the Olympic loams consists chiefly of fir. Considerable cedar, hemlock, and spruce is also found, besides a mixed growth of salal, vine maple, and berries of various kinds. On account of the rough topography and rocky character of the soil, practically none of the type has been cleared and put under cultivation. Along Hood Canal and throughout the type are small V-shaped valleys whose steep slopes could be utilized for berries, fruit, etc., but are entirely too rough for cultivation to ordinary crops. Small flats are also found scattered throughout the areas mapped suited to all the crops grown in the region. Because of their inaccessibility and small extent they would probably not justify cultivation. The greater part of the Olympic loams is much better adapted to the production of timber than to general farm crops, and for this reason it is recommended that the type be used for forestry purposes. This is advisable not only because the steep topography and shallow soil unsuits it for the growing of crops, but because the removal of the forest covering favors erosion. The greater part of the type is still covered by the original forest growth, which includes some of the most valuable timber in the State. In the northeastern part of Chehalis County, in the vicinity of Summit, there is a considerable area of logged-off land, whose surface is less broken and not so stony, much of which could be profitably utilized for farming. Some of this area can be bought as low as \$5 an acre, while many of the timbered tracts are held for \$500 or more.

RECENT ALLUVIAL SOILS.

PUGET SERIES.

The Puget series includes the recent alluvial soils occupying the valleys and delta flats of the rivers which traverse the glaciated region of the Puget Sound Basin. The types of this series are quite uniform in color, texture, and topography in all parts of the Puget Sound region. They are derived from glacial material which has been brought down by the rivers and deposited over the valleys or in the shallow bays at the mouths of the streams in times of flood, eventually building up broad level delta lands. The types are characterized by flat to gently sloping topography and by brown to drab

or gray friable soils usually with a high organic matter content, underlain by light-brown to drab material ranging from porous sands to compact silt or silty clay subsoils.

The lighter textured types of the series occur near the main stream channels where the coarser material was deposited by the swifter currents. Farther back from the stream the sandy deposits have been covered by finer sediments of silt and clay, which were laid down in the quieter waters. In depressions, which remained flooded for long periods in each overflow, the sediments of silt and clay are often many feet deep, giving rise to the heavier types of the series. Over the greater part of the valleys the underlying sandy deposits are encountered at from 10 to 30 inches below the surface.

PUGET FINE SANDY LOAM.

The Puget fine sandy loam consists of from 12 to 15 inches of gray to light-brown fine sandy loam containing at times a rather high percentage of silt. This fine material increases in proportion as the boundary of the Puget silt loam is approached, as here the materials grade imperceptibly into each other. The subsoil is lighter in color and texture, and consists of a fine sandy loam to fine incoherent sands. Below the second foot a thin stratum of mottled silty clay is frequently encountered, and both soil and subsoil are often marked with reddish-brown iron strains.

The soil is alluvial in origin, being derived from the finer sands and silt which have been deposited by the swifter currents of the rivers during times of overflow.

The Puget fine sandy loam is of limited extent, being found in Mason County in only one small body near the mouth of the Skokomish River and as a narrow strip in Thurston County along the Nisqually River.

The topography of the type is level, except where the surface is cut by occasional stream channels. As it occupies the lowest position in the valleys, all of it is subject to overflow. The floods usually occur at such seasons of the year that no material injury is done to growing crops.

Very little of the type is under cultivation in this area, such areas being used for the production of hay and oats. The soil should be well adapted to most of the fruits, especially apples, pears, and plums, and seems also to be well suited to blackberries and strawberries. The soil is also well adapted to potatoes and other truck crops.

The original forest growth on the Puget fine sandy loam consists of fir, cedar, poplar, and spruce.

The following table gives the results of mechanical analyses of the soil and subsoil of the Puget fine sandy loam:

Mechanical analyses of Puget fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25254.....	Soil.....	0.4	0.3	1.8	24.0	20.3	43.1	10.0
25255.....	Subsoil.....	.1	.3	3.1	66.7	21.0	6.7	1.7

PUGET SILT LOAM.

The Puget silt loam, to an average depth of 12 to 24 inches, is a gray, light-brown, or mottled gray and brown silt loam sometimes carrying a relatively high percentage of very fine sand. This is underlain by light-brown to gray silty fine sand or fine sandy loam which is usually mottled with yellow and brown iron stains. Mica flakes are of frequent occurrence in both soil and subsoil. When dry the surface has an ashy-gray appearance and the structure is loose and mellow, making it an easy soil to cultivate.

The type is alluvial in origin and represents the reworked glacial material from the hills brought down by the streams in times of flood and deposited in comparatively quiet waters.

Only two bodies of the type are mapped in the area surveyed. One of these occurs near the mouth of the Nisqually River, in Thurston County, and the other in Mason County along the upper course of the Skokomish and its larger tributaries.

In the main the topography of the type is level, though the surface is sometimes marked by shallow depressions representing old stream channels which are still used by the rivers in times of flood. Except for the high waters which cover the greater part of the type each winter, the soil is not seriously affected by lack of drainage. Like the Puget silty clay loam and the Puget silty clay, the soil would be benefited by tile drainage, which would hasten the removal of the flood waters in the spring and permit of earlier seeding than is now possible.

The native vegetation consists of fir, cedar, cottonwood, and spruce.

Only that part of the type occurring along the Nisqually River is under cultivation. The principal crops grown are hay, oats, and potatoes. Hay yields from 2 to 3 tons per acre, oats from 75 to 100 bushels, and potatoes from 200 to 300 bushels per acre.

The type is valued at from \$25 to \$150 an acre, depending upon location and improvements.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Puget silt loam:

Mechanical analyses of Puget silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25258.....	Soil.....	0.0	0.2	0.1	2.0	4.4	82.7	10.5
25259.....	Subsoil.....	.1	.4	3.5	37.4	22.9	32.5	3.7

PUGET SILTY CLAY LOAM.

The soil of the Puget silty clay loam consists of 10 or 15 inches of gray to light-brown, heavy silty clay loam containing a high proportion of organic matter in various stages of decomposition. This material is underlain by gray silty clay loam or silty clay slightly marked with iron stains. Both soil and subsoil are frequently mottled with yellow, a feature which is more common in the lower depths.

The soil is alluvial in formation and represents the finer particles deposited by the river in comparatively quiet waters during periods of overflow. As the type is flooded more or less each year, the material is still being added to, with the result that the surface is apt to change slightly in character with each successive flood.

The body of Puget silty clay loam mapped in the present survey is very limited in extent, including not more than two and one-half sections. The type occurs as an irregular body at the mouth of the Skokomish River in Mason County.

The topography is level, and the surface is only a few feet above the level of the river. Because of its low position the type is always in danger of overflow, especially that part lying nearest the mouth of the river. The floods rarely occur during the growing season and as the chief crop produced is hay, which is not materially injured by overflows, the flooding of the land with its accompanying deposits of silt is more of an advantage than a detriment. Tile drains, however, would be beneficial in that they would hasten the removal of the flood waters in the spring and permit the soil to warm up at an earlier date than is possible at present.

Hay is the chief crop produced on this type. Clover and timothy yield from $1\frac{1}{2}$ to 3 tons per acre. Small grains are grown to a limited extent, especially oats, the yield of the latter being from 59 to 100 bushels per acre. The soil has been used to a limited extent for many years in the production of cherries, apples, and other tree fruits, and notwithstanding the fact that the orchards have been badly neglected profitable yields are being secured.

Under favorable drainage conditions the Puget silty clay loam has a high agricultural value.

PUGET SILTY CLAY.

The soil of the Puget silty clay consists of 10 to 15 inches of drab to slightly mottled silty clay containing a relatively high percentage of organic matter in various stages of decomposition. The surface material is underlain by a heavy silty loam or silty clay subsoil, slightly mottled with iron stains and very similar in texture to the surface soil, but containing a smaller amount of organic matter.

This soil is found only as a narrow strip bordering the shallow waters at the northeast end of Camano Island and at the head of Livingston Bay in Island County. The topography is nearly level, these areas having only a slight elevation above high-water level. This low position causes parts of the type to be overflowed at times of high water and the cultivated areas are diked to keep out these waters. The soil as a whole has poor natural drainage, and artificial systems are necessary to permit cultivation.

The Puget silty clay is a marsh type and owes its origin to fine beds of alluvial sediments brought down from the mountains by the Stilaguamish River and laid down in the shallow waters near its mouth as a delta deposit. Upon these finer delta deposits has accumulated the more or less decayed growth of grasses which has added organic matter.

The type is planted almost exclusively to oats and seems remarkably well adapted to this crop. The average yield runs from 80 to 100 bushels per acre, and yields of 150 bushels are sometimes recorded on favorable locations. Yields of 3 to 4 tons per acre of timothy and red clover hay are also common. Potatoes do well, but have a tendency to scab.

Land of this type is all under cultivation and valued at \$200 to \$300 an acre.

The following table gives the average results of mechanical analyses of the soil and subsoil of this type:

Mechanical analyses of Puget silty clay.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
14073, 14075, 16986, 17721, 22063, 22065.	Soil.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
14074, 14076, 16987, 17722, 22064, 22066.	Subsoil..	.1	1.1	0.5	1.2	3.2	63.5	30.4
		.2	.7	.4	.9	5.0	66.0	26.4

CHEHALIS SERIES.

The Chehalis series comprises the alluvial soils occupying the valleys of the streams which traverse the region of residual soils. The

soils vary considerably in color. The majority of the types have a gray to reddish-brown color, but some of the heavier types are dark brown to black. The soils of this series are derived from material which has been eroded from the silty residual soils of the uplands and redeposited over the valleys at times of floods.

The lighter textured soils occur near the main stream channels where the coarser material was laid down by the swifter currents, while the heavier clay or clay loams occupy the broad shallow basins farther back from the streams which remained in a flooded condition for long periods after each overflow. Small areas of these alluvial soils are at present subject to overflow at times of high water.

The topography of these valleys is almost level, but the greater proportion of the land has a sufficient elevation above the present level of the stream channels to insure good natural drainage. The soils of the Chehalis series are very productive and are classed amongst the best agricultural soils of the area.

CHEHALIS LOAM.

The Chehalis loam is an inextensive type. Only small bodies of it are found. The soil consists of about 12 inches of yellowish-brown to dark-brown loam overlying a dark-brown sandy loam. Near the banks of the rivers the soil is a light-brown, fine sandy loam several feet deep. Farther from the rivers, where the loam borders the silty clay loam type of this series, the two soils merge gradually into one another, so imperceptibly that the boundaries between them in many cases could be drawn only arbitrarily.

The soil is of recent alluvial formation and represents the coarsest material deposited by the swiftly flowing currents of the river in times of overflow.

The type is very limited in extent, occurring only as narrow strips along the banks of the Chehalis River in the vicinity of the city of that name.

Next to the river, where the soil is more sandy, the surface is slightly rolling, owing to slight depressions and low ridges. Farther back the topography is nearly level. The drainage as a rule is good.

The soil is well adapted to fruit and to truck crops. Hops do well on the type, but the profits of the crop are influenced more by fluctuations in the price than by variations in the yield of the crop. The land is practically all under cultivation, and much of it is in a highly improved condition. Values range from \$100 to \$200 an acre, this high figure being largely due to the nearness of the type to Chehalis.

CHEHALIS SILTY CLAY LOAM.

The typical development of Chehalis silty clay loam consists of from 10 to 15 inches of a brown to reddish-brown silty clay loam, with an average depth of 12 inches. The soil is mellow and friable

and can be worked under a wide range of moisture conditions. In places the soil is light brown to yellowish brown to a depth of 3 feet or more, the lighter color being due to somewhat higher elevation and consequent better drainage.

The subsoil from 12 to 36 inches consists of a light-brown to reddish-brown mellow silty clay loam. Below this depth the material sometimes becomes slightly lighter in color, and as the type approaches the river it becomes lighter in texture as well. In the depressions where the drainage is poor, the subsoil is apt to be a little heavier and darker in color than on the well-drained areas. Under these conditions the subsoil is also frequently mottled.

South of Gate the soil is more shallow and heavier in texture, overlying a compact clay loam or clay. In Chehalis County the type includes small strips of fine sandy loam bordering the streams, but these were too narrow to be shown on a map of the scale used. Small gravelly areas too limited to be shown on the map are also included with the type.

The type closely resembles the Chehalis clay in position, topography, and method of formation, but differs from it in having a darker color and a lighter textured soil and subsoil.

The Chehalis silty clay loam is of alluvial origin and represents deposits continuing through a long period of years. Those of more recent date, which represent the greater portion of the type, are the result of annual overflows. In nearly every case where such condition occurs the soil is of a darker color than that of the slightly higher elevations which are not so often flooded. The Chehalis silty clay loam was laid down by comparatively quiet waters, whose movement was somewhat more rapid than that which deposited the finer material composing the Chehalis clay, but not so swift as were those which left the loam type along the river bank. Like all the soils of the Chehalis series, the soil is derived from washings from the unglaciated uplands, in which respect it differs from the Puget silt loam, which is the product of redeposition of glacial material.

The type is the most common bottom land soil of Chehalis and southwestern Thurston Counties, being found on all the principal streams as valleys from one-eighth of a mile to 1½ miles in width. The largest body of the type is found along the Chehalis River, extending from the Lewis-Thurston County line to a few miles beyond Montesano. Other important bodies are found along the Skookum Chuck, Satsop, Humptulips, North, Wynooche, and Wishkah Rivers and most of the branches leading into these streams.

With the exception of the lower part of the Chehalis River Valley, which is cut by abandoned stream channels, the topography of the Chehalis silty clay loam is fairly level, sloping slightly down the valley. Now and then slight depressions occur, but their extent is

small. In such places the drainage is rather poor, and as the areas are flooded each winter by overflow waters from the river, it is usually rather late before plowing and seeding can be effected. The greater part of the type is well drained, though the use of tiles would be beneficial.

In its native state the type is covered with fir, cedar, spruce, alder, and vine maple and a dense growth of fern and underbrush.

The Chehalis silty clay loam is one of the most valuable soils in this region. It is level, well drained, productive, and easily worked. It is well adapted to all of the small grains grown in the western part of the State and to hops, clover, and the various kinds of grasses. It is an excellent soil for fruit, though the trees are said to be short lived. This is undoubtedly due in many cases to lack of care and attention on the part of the grower, and in other cases to inadequate drainage of the subsoil, small grains and tree fruits being entirely different in their requirements in this respect. The chief crop produced is oats, the yields ranging from 60 to 125 bushels, with an average of from 70 to 80 bushels per acre. Wheat returns from 30 to 50 bushels, with an average of 40 bushels per acre. As the quality of it is poor, none is milled, the entire crop being used as feed for stock. Clover yields from 2 to 3 tons per acre, and other hay crops in like proportion. Potatoes yield from 200 to 300 bushels per acre, but are in danger of being ruined by midsummer frosts.

In the vicinity of the larger towns in the Chehalis River Valley well-improved farms on this type of soil are held at from \$200 to \$300 an acre. Farther back unimproved or partially cleared land is valued at from \$40 to \$100 an acre.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Chehalis silty clay loam:

Mechanical analyses of Chehalis silty clay loam.

Number.	Description.	Fine	Coarse	Medium	Fine	Very fine	Silt.	Clay.
		gravel.	sand.	sand.	sand.	sand.		
25180.....	Soil.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
		0.0	0.1	0.1	2.6	5.8	64.8	26.4
25181.....	Subsoil.....	.0	.0	.2	1.9	1.0	64.7	32.1

CHEHALIS SILTY CLAY.

Where typically developed the Chehalis silty clay to an average depth of 12 inches is a brownish-gray to bluish-gray heavy silty clay usually mottled with yellow and carrying a high percentage of organic matter. When dry it is decidedly brown. The subsoil is a bluish-gray to slate-colored silty clay, also frequently mottled with yellow and lighter shades of gray, although the mottlings are less

pronounced than in the surface soil. Brown iron stains occur in both soil and subsoil, being somewhat more abundant in the former. The type is often overlain by a shallow covering of partially decomposed vegetation, while layers of peaty material and the remains of deadwood are frequently encountered in both soil and subsoil.

As mapped the type includes numerous small areas of peat and muck. Where properly diked and drained the type is cultivated without difficulty.

The Chehalis silty clay consists of the finer deposits of silt and clay brought down by streams and left in the quiet waters about Grays Harbor. This material is similar in formation to the Puget silt loam, but the sediments composing the former have been derived from residual uplands, while those of the latter came chiefly from glaciated uplands.

With the exception of a few small bodies in the Chehalis River Valley and one body at the mouth of the Chehalis River all of the type occurs in the vicinity of Grays Harbor. A strip of varying width surrounds a large part of this body of water, while areas from one-quarter to 2 miles wide extend for considerable distances up all the streams entering the harbor. The largest body occurs at the mouth of the Chehalis River and reaches nearly to Montesano.

The topography of the Chehalis silty clay is low and flat, the greater part of the type lying very little above high tide. It is intersected by numerous small brackish sloughs. During the winter months much of the type is inundated and in summer the water table is so near the surface as to necessitate diking and draining before crops can be successfully grown.

The native vegetation of the Chehalis silty clay consists of a stunted and inferior stand of fir, cedar, spruce, alder, and willow. The treeless areas are covered by a heavy growth of marsh grasses.

At present much of the type is of little or no agricultural value. Small areas that have been properly diked and drained produce very good truck crops, especially cabbage and celery. This soil is very fertile and once placed in the proper condition would undoubtedly yield profitable returns with a wide range of crops.

Below are given the results of mechanical analyses of samples of the soil and subsoil of the Chehalis silty clay:

Mechanical analyses of Chehalis silty clay.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
25182.....	Soil.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
	Subsoil.....	0.1	0.7	0.3	0.5	1.2	65.4	31.4
25183.....		.0	.4	.2	.4	.2	89.8	28.9

CHEHALIS CLAY.

The Chehalis clay consists of from 10 to 12 inches of dark-colored, heavy, tenacious clay mottled with yellow and orange. When dry the surface varies from dark-gray to slate color, but when wet it is decidedly black. In the latter condition the material is sticky and compact, and on drying becomes sun-cracked, hard, and difficult to handle. In the lower places considerable organic matter is found in the soil, which relieves the difficulty of cultivation to some extent.

The subsoil, from 12 to 36 inches, consists of mottled gray and orange, waxy clay overlying gray clay of massive, compact structure. Sometimes the subsoil is of a dark-drab to slate color, with slight marks of reddish-brown iron stains in the lower depths.

A few small areas which were not quite typical have been included with this type. They are usually slightly lighter in texture. One body northeast of McIntosh, in Thurston County, and another east of Elma, in Chehalis County, have a dark-brown to grayish-brown soil mottled with yellow and gray, while the subsoil is gray mottled with yellow and brown.

The Chehalis clay is very limited in extent, being found in a few small bodies in southeastern Thurston County. The largest of these is $2\frac{1}{2}$ miles south of Bucoda, along a branch of Hanford Creek. One small body is also found east of Elma, in Chehalis County.

The origin of Chehalis clay is entirely alluvial, the material having been built up in the low depressions by the deposition of the finest particles carried by the streams in times of overflow. The marked absence of the various grades of sands in this soil indicates that the material was laid down by comparatively quiet waters whose currents were too slow to carry the coarser materials.

The topography of the type is uniformly level, and as it occupies the lowest depressions in the stream and river valleys the greater part of it is inundated during the late fall and winter months. Because of this low position and the highly impervious nature of the soil material, the surface remains wet and sticky for a considerable time after the flood waters recede. The type is always the last to be plowed and sown in the spring, with the result that crop growth is frequently curtailed and suffers during the midsummer drought. The drainage is poor and could best be supplied by open ditches, supplemented by tile drains for laterals.

The greater part of the Chehalis clay is used in the production of small grains, oats being the chief crop grown. The type produces a heavy growth of straw, which gives a high tonnage when cut for hay. When the crop is allowed to ripen, as it usually is, the yield ranges from 60 to 100 bushels per acre, with an average of about 75 bushels. Very little wheat is grown, as the quality is poor, but the yield is

high. The soil is well adapted to hay of all kinds. Large fields of timothy and clover have averaged $2\frac{1}{2}$ tons per acre, and larger yields have been reported for smaller areas. Because of the prevalence of summer frosts, the type is not well adapted to potatoes or other vine crops nor to the production of fruits. For hay and grain crops the Chehalis clay is considered one of the best soils in the region.

The land is held at from \$75 to \$125 an acre, depending largely on location and drainage.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Chehalis clay:

Mechanical analyses of Chehalis clay.

Number.	Description.	Fine	Coarse	Medium	Fine	Very fine	Silt.	Clay.
		gravel.	sand.	sand.	sand.	sand.	cent.	cent.
25188.....	Soil.....	0.0	0.1	0.1	0.7	0.2	24.0	74.6
25189.....	Subsoil.....	.0	.0	.0	.3	.5	20.7	78.3

MISCELLANEOUS TYPE.

ELD SILTY CLAY LOAM.

The soil of the Eld silty clay loam consists of 14 to 24 inches of reddish-brown to red silty clay loam containing a few iron pellets and a small amount of gravel. The subsoil is usually a heavy silt loam or silty clay loam which in the better-drained portions of the type is a reddish brown, sometimes mottled with gray. In the poorly drained areas the gray color frequently predominates. A phase of the type occurring in the western part of Mason County and in the vicinity of Quilcene, Jefferson County, consists of red, heavy loam or clay loam about 14 inches deep overlying red to reddish-brown fine sandy loam or loam. The structure of the soil is loose and friable and permits of cultivation under a wide range of moisture conditions. In the lower areas, however, the type is frequently water soaked till late in spring, somewhat retarding farm operations beyond the best date for seeding.

The Eld silty clay loam is of recent alluvial formation, being derived largely from the residual soils of the basaltic hills, although in some cases it has been influenced to a considerable extent by material from other surrounding soils.

Several bodies of Eld silty clay loam have been mapped in the area. These have been found in the western part of Thurston County, the most important of which is in the vicinity of Little Rock. Other small bodies are found in Mason and Jefferson Counties in the vicinity of Hoodsport and Quilcene.

The type has a level topography and as a rule is well drained, although considerable areas in Thurston County are in need of artificial drainage.

Practically all of the type has been cleared and placed in cultivation. All of it is adapted to hay and grains and the better drained areas to potatoes, truck crops, and fruits. The chief crops grown are oats, hay, and potatoes. Oats yield from 45 to 60 bushels per acre and hay from $1\frac{1}{2}$ to $2\frac{1}{2}$ tons per acre.

Values range from \$40 to \$100 an acre, depending on location and improvement.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Eld silty clay loam:

Mechanical analyses of Eld silty clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
25211, 25213.....	Soil.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25212, 25214.....	Subsoil.....	0.4	1.7	1.7	6.3	6.7	58.1	25.0
		.4	1.3	1.9	8.3	10.2	61.0	17.0

TIDAL ESTUARINE DEPOSITS.

MISCELLANEOUS TYPE.

TIDAL MARSH.

The areas mapped as Tidal marsh have only a slight elevation above tide level, and are traversed by numerous small brackish sloughs. They support a dense growth of marsh grasses, and the surface is sometimes composed of a thick layer of partially decomposed fibrous organic matter formed from the decay of this vegetation.

Tidal marsh in most cases has been formed through the accumulation of materials held in suspension by the streams and deposited in shallow waters of the bays into which the streams empty. The small area which occurs at Port Townsend consists of the finer material composing the Townsend gravelly sandy loam washed down into the low depression and lacks the marshy condition common to the rest of the type.

The type is of limited extent occurring only at the mouth of the Nisqually River, at Port Townsend, and on three small islands in Grays Harbor.

Because of its low, poorly drained condition, the type has very little agricultural value except for the small amount of pasturage which it produces.

OLDER ALLUVIAL DEPOSITS.

DUNGENESS SERIES.

The soils of this series occupy a broad level to gently undulating plain which slopes gradually from the base of the rolling uplands at the foot of the Olympic Mountains to the bluff bordering the coast line of the Strait of Juan de Fuca. The soils are light brown to gray and contain a considerable amount of fine sand and silt. The subsoils are lighter in color than the surface soils, and consist mainly of compact deposits of silt and fine sand.

The soils of the Dungeness series are derived from sediments of silt, clay, and fine sand which were laid down by the flood waters of the Dungeness River before its channel had been cut down to the present level.

The river rising in the high mountains to the south had a considerable fall until it reached the level plain or bench land lying between the foothills and the coast. Here it branched off into several shallow channels, and at times of high water the adjacent level areas were flooded and the fine sand, silt, and clay held in suspension by the water of the stream was deposited over the older formations.

The Dungeness soils are not at present subject to overflow, except a very small area bordering the present channel of the stream near its mouth.

DUNGENESS SILT LOAM.

The Dungeness silt loam to a depth of 15 inches consists of gray silt loam of compact structure. When dry the surface is almost white, a condition due in some degree to the scarcity of organic matter in the soil material. The subsoil varies, but is most frequently a gray or yellowish-gray silty clay loam or silty clay. In many cases the material ranges from gray to light yellowish-brown silty fine sandy loam to heavy silt loam. In every case the structure of the subsoil is close and compact, and the color, whether gray or brown, is marked by reddish-brown iron stains. If plowed in the proper moisture condition, the soil breaks up loose and mellow, but the high silt and clay content renders it quite sticky and adhesive if plowed when wet.

A phase of this type occurs in the northeast quarter of section 9 about 3 miles northwest of Sequim, where the soil is a dark-brown heavy silt loam about 14 inches deep, resting on a yellowish-brown heavy silt loam. Below the second foot the material is slightly marked with reddish-brown iron stains.

The Dungeness silt loam consists of silt and clay deposited over a comparatively level plain in the form of an alluvial fan. The greater part of the type is not recent alluvial in the true sense of the

term, but is an ancient deposit laid down by the Dungeness River at a time when the stream stood at a higher level than it at present occupies. In the vicinity of Dungeness, where the type lies at a lower level along the river, the material consists of recent alluvium laid down during times of flood. Here the soil and subsoil are usually of somewhat heavier texture than is found on the higher land and closely resembles the Puget silty clay. The bodies, however, were of too small extent to warrant a separation of the types on a map of the scale used.

The type is not an extensive one, being found only in a few small areas near the mouth of the Dungeness River. The largest and most important occurs at Dungeness, whence it extends as a narrow strip for 2 miles or more along the west side of the river. Other areas are found to the south and west of Sequim.

The surface of the type is uniformly level, except for a slight difference in elevation next to the river bank. At present most of the type lies above the flood plain of the streams, though during years of unusually high water a narrow strip near the channels is flooded for short periods. The Dungeness silt loam holds water well and rarely suffers from drought. Over a part of the type the water table stands so near the surface as to give the effect of subirrigation. On most of these places blind drains are used. As the soil dries out the outlets of the drains may be stopped, when the water will collect in the soil until the moisture requirements are met.

Except in the vicinity of Dungeness, where the type is nearly all under cultivation, the greater part of the Dungeness silt loam is still uncleared. For oats, clover, alfalfa, and grasses the soil is excellent, and a large acreage of it could be profitably cleared and devoted to these crops. Most of the oats grown are cut for hay and used as dairy feed, the yield ranging from 3 to 5 tons per acre. Clover, alfalfa, and other hay crops yield from $2\frac{1}{2}$ to 4 tons per acre. When the oats are allowed to ripen and are thrashed for grain the yield ranges from 60 to 80 bushels per acre. Very high yields of wheat are secured, but the softness of the berry unsuits it for milling purposes, and the entire crop is utilized as feed for stock. The type is well adapted to truck and berries of all kinds, but these crops are grown but very little commercially.

This type of soil was originally heavily timbered with fir, cedar, cottonwood, and a small amount of spruce and pine.

The Dungeness silt loam is considered one of the best soils for general farm crops found in the area surveyed. The price of the land varies from \$25 to \$100 and more an acre, depending on improvements and location.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of this type:

Mechanical analyses of Dungeness silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25203.....	Soil.....	0.2	0.5	0.4	1.0	9.2	73.1	15.4
25204.....	Subsoil.....	.0	.6	.2	2.3	9.4	76.8	10.4

DUNGENESS FINE SANDY LOAM.

The surface material of the Dungeness fine sandy loam consists of about 12 inches of gray to light brownish gray silty fine sandy loam of a close, compact structure. Slightly more organic matter is found in this soil than in the Dungeness silt loam and in consequence the color is somewhat darker. The subsoil, from 12 to 36 inches, varies from a yellowish-gray fine sandy loam to compact gray silt loam containing a high content of very fine sand. Very frequently both the soil and subsoil have a slightly mottled appearance, due to the presence of reddish-brown iron stains. Usually the soil is easily worked, but has a tendency to run together if plowed when too wet.

The type has been formed in the same manner as the Dungeness silt loam, namely, by the deposition of material over a comparatively level plain in the form of an alluvial fan. Like the silt loam type, this material is not recent alluvium, but is largely an ancient deposit which has weathered considerably since its deposition. Along the banks of the Dungeness River, where a narrow strip of the type is occasionally overflowed, the formation of the soil is more or less recent. In such locations the material would doubtless have been correlated with the soils of the Puget series in a detailed soil survey, but the areas so affected were all of too small extent to be separated on a map of the scale used.

Though the Dungeness fine sandy loam is of comparatively small extent, it is nevertheless a very important type. The largest body is found between Sequim and Dungeness, where it spreads out over the upper part of the flat which once constituted the flood plain of the Dungeness River. Other important bodies are found at Green Point and along the lower part of the Elwha River.

The Dungeness fine sandy loam has a uniformly level topography, with just about sufficient slope to give good surface drainage. The greater part of the type lies in such position that irrigation could be cheaply effected, though as yet none of it has been so improved.

The type was formerly covered by a heavy growth of fir, cedar, cottonwood, and spruce, most of which has now been cut off for lumber.

Only a small percentage of the Dungeness fine sandy loam is under cultivation. The crops most commonly grown are those used for forage and consist of oats, clover, alfalfa, and grasses. Some wheat is raised and used for feed. The type seems well suited to the production of apples, blackberries, raspberries, and strawberries, as well as all garden crops. These are grown only for home use, the dairy industry being the one which is given first importance. The yields secured on this type are about the same as those obtained on the Dungeness silt loam. On account of the slightly higher position and higher content of sandy material in the type, the soil dries more quickly and warms up at an earlier date in spring than does the latter type. For this reason crops requiring an early maturity would probably do better on this soil than on the Dungeness silt loam. Though only a small acreage of the Dungeness fine sandy loam is under cultivation, the entire type has qualities which would justify immediate clearing for agricultural purposes. Besides being level, well drained, and easily worked, it is early, well watered, and productive. Though irrigation is not at all essential for successful crop production on this soil, such improvement would add greatly to the yields and make the type one of the most valuable found in the region. At present the value ranges from \$25 to \$100 or more an acre, depending on improvement.

The Dungeness fine sandy loam has a dark sandy phase, indicated upon the soil map, consisting of from 8 to 12 inches of black fine sandy loam. The subsoil is variable being sometimes a dark colored fine sandy loam or silty fine sandy loam of somewhat heavier texture, and sometimes a light-colored fine sandy loam, from 12 to 26 inches deep, overlying light-colored clay loam or clay. Areas were also found where the underlying material was made up chiefly of gray fine sand. In such cases reddish-brown iron stains were not uncommon. As a rule the soil contains a large amount of organic matter, giving it a loose structure and rendering it easy to cultivate. Only small bodies of this phase of the type were mapped, one being west of Dungeness and the other in the vicinity of Irondale.

This phase of the soil is very productive and is adapted to all the crops grown in the area. Potatoes do well, yielding from 150 to 250 bushels an acre. Hay, oats, and other small grains are also produced with good success.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Dungeness fine sandy loam:

Mechanical analyses of Dungeness fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25207.....	Soil.....	1.0	5.3	8.1	20.1	19.7	36.8	9.0
25208.....	Subsoil.....	.9	4.0	6.2	20.9	18.7	39.2	9.8

MISCELLANEOUS TYPE.

SEQUIM GRAVELLY SANDY LOAM.

The soil of the Sequim gravelly sandy loam consists of brown to black sandy loam, or heavy sandy loam sometimes approaching a loam in texture, 12 to 15 inches deep, containing a large amount of glacial stones and gravel. The subsoil is a dark brown to black heavy sandy loam which grades at from 20 to 30 inches into lighter colored material containing a high proportion of cobblestones and gravel. The subsoil is usually more gravelly than the soil, being in places little more than a mass of cobbles and gravel which range from a few inches to a foot or more in diameter. Below 30 inches and sometimes at a lesser depth the cobbles and gravel are mixed with a high percentage of fine rock flour which when saturated with water cements into a compact mass, thus preventing to a considerable degree the downward passage of water so characteristic of most gravelly soils. Over the greater part of the type the stones and bowlders are present in sufficient numbers to interfere seriously with cultivation, and where the land is cropped it has been found necessary to remove them to a depth of 10 inches or a foot. This can be done at a cost of from \$7 to \$10 an acre.

The Sequim gravelly sandy loam occupies an elevated delta plain along the Dungeness River at the base of the Olympic Mountains, consisting mainly of reworked and redeposited glacial material. As the river rushed down from the mountains with a high velocity it rolled bowlders, cobbles, and gravel, which, on reaching the plain where the current subsides, were spread out and deposited as a fanlike formation. At the base of the mountain, near the opening of the narrow V-shaped valley where the velocity of the river met its first check, a large proportion of the larger stones and bowlders were deposited, while the cobbles, gravel, and fine material were carried on and left over the level plain.

The Sequim gravelly sandy loam is found only in Clallam County, where it occurs in two small bodies aggregating about $2\frac{1}{2}$ square miles. The larger area is found at Sequim, while the smaller is about 3 miles to the west.

The type has a uniformly level topography, with an excellent fall for irrigation and drainage purposes.

Except for a few small clumps of fir and hemlock, the areas of Sequim gravelly sandy loam are entirely prairie, covered only by a sparse growth of native grasses.

Until recently the type has been considered of little value, but with the establishment of irrigation it has become the highest priced land of the area. The crops grown are chiefly clover, oats, Canada field peas, and alfalfa. Apples, pears, cherries, plums, strawberries, blackberries, and raspberries are also grown on the type. Clover

does exceptionally well, yielding two cuttings per season of from 1 to 2 tons. Oats, when cut for hay, yield from 3 to 4 tons per acre and sell for about \$10 or \$12 a ton in the local market. Nearly all of the grain grown is cut before it ripens and used for hay in the dairy business. When allowed to mature oats yield from 60 to 85 bushels, with an average of about 70 bushels per acre. Wheat yields well, but the berry is soft and the crop is used only for feed. The Canada field peas are grown mostly with oats, the yield of the two crops being from 3 to 4 tons of hay per acre, which usually sells for about \$12.50 a ton locally. Potatoes yield on an average about 200 bushels per acre and are of good quality. Vegetables do well, but are grown only for home consumption. Considerable fruit and berries have been put out, but fruit growing is still in the experimental stage.

Under irrigation the type is very productive and is in demand. At present prices range from \$50 to as high as \$300 an acre, the latter price being paid for well-improved property. Without irrigation the soil has very little agricultural value. All of the type is favorably located for irrigation, an abundant supply of water being available at small expense from the near-by Dungeness River.

The results of mechanical analyses of samples of the soil and subsoil are given in the following table:

Mechanical analyses of Sequim gravelly sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
25267.....	Soil.....	11.7	18.9	10.0	19.3	9.3	21.0	9.9
25268.....	Subsoil.....	15.9	17.8	10.4	20.6	10.8	20.1	4.9

SOILS DERIVED FROM MIXED GLACIAL, COLLUVIAL, AND ALLUVIAL MATERIAL.

ELMA SERIES.

The soils of the Elma series occupy level to gently rolling areas bordering the valleys of small streams. Their characteristic color is brown to reddish brown. They are derived from the fine material washed down from the adjacent uplands occupied by the silty soils and deposited over areas which were originally covered by deposits of glacial gravel.

In some areas the finer material has been laid down as a shallow covering over the coarse gravelly deposits, while in others the silt, clay, and fine sand have become mixed with the coarse glacial material, forming a soil which contains a large amount of gravel and small, rounded cobbles throughout the entire 3-foot section. The soils of this series, as a whole, have good natural drainage and are very productive.

ELMA GRAVELLY SANDY LOAM.

The Elma gravelly sandy loam consists of a reddish-brown, dark-brown, or black gravelly sandy loam which carries considerable fine silty material and at times large amounts of organic matter. A few rounded glacial cobbles are found strewn over the surface and distributed through the soil. It is underlain by a brown or reddish-brown gravelly loam or sandy loam in which the percentage of rounded glacial rocks and coarse gravel is much greater, while the fine material is proportionately less. The type includes some small areas of a silty loam as well as depressions of Muck and Peat. As the soil is level, loose, and friable it lends itself readily to the use of all kinds of improved farm machinery.

The Elma gravelly sandy loam consists of intermingled material of glacial and alluvial origin. The coarser material, which makes up the greater proportion of the subsoil as well as a small part of the soil, represents a glacial sediment from which the fine material has been largely washed by swift glacial streams. The character of this material, especially in the surface soil, has been influenced to a considerable extent by late additions of alluvial material derived chiefly from the silty red residual soils of the surrounding hills.

Only two bodies of Elma gravelly sandy loam are found in the area, both of which are in Chehalis County. The largest body covers an area of approximately 4 square miles and is located in the vicinity of Summit. A smaller body occurs along the Little Chehalis River about 3 miles northwest of Porter.

The topography of the type is comparatively level, although many small depressions occur, especially along the stream channels. As a rule the type is found at a somewhat lower elevation than the surrounding soils, and for this reason much of it is flooded during the rainy season. Owing to the very porous nature of the soil the surplus waters drain off rapidly. Crops grown on it do not succumb to drought as readily as on other soils of like texture, since the water table is comparatively near the surface. Much of the type is favorably situated for irrigation with comparatively little cost, and the increased yields that could be secured would doubtless more than pay for the extra expense incurred.

The original forest growth consists of alder, willows, fir, cedar, and a few spruce trees. Much of the type has been logged, but only a small percentage is under cultivation.

The Elma gravelly sandy loam is well adapted to all crops grown in the region. The principal crops are oats, hay, potatoes, and small fruits. Oats produce an average of 60 bushels per acre, although they are generally cut for hay, the yield being 3 to 4 tons per acre. Clover hay returns from 2 to 3 tons per acre. Potatoes

do exceptionally well on this soil, the yield ranging from 150 to 300 bushels per acre. Very little wheat is grown on the type, although the yields secured compare favorably with those on other soils of the area.

Improved areas of Elma gravelly sandy loam can be had for \$100 an acre. The unimproved logged-off lands are valued at \$10 to \$15 an acre.

The results of mechanical analyses of samples of the soil and subsoil are given in the following table:

Mechanical analyses of Elma gravelly sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
26217.....	Soil.....	12.4	17.7	7.2	6.3	3.0	32.4	21.4
26218.....	Subsoil.....	17.2	28.2	10.1	6.0	1.8	22.8	13.7

ELMA LOAM.

The Elma loam consists of about 12 inches of light-brown to brown loam or sandy clay loam. On the surface of dry cultivated fields this material is considerably lighter in color, often approaching gray. It is underlain by a somewhat lighter colored sandy clay loam, or loam which becomes heavier in texture and more compact with depth. At 3 to 8 feet an incoherent mass of coarse, rounded glacial gravels appear, which extends to considerable depths. Both soil and subsoil contain many mica flakes.

As mapped the type includes many small areas of a sandy loam and fine sandy loam, as well as small depressions of silty loam or silt loam. Such areas are of too limited extent to be shown in a survey of this character. The soil is mellow, level, and well drained, and lends itself readily to the use of all kinds of improved farm machinery.

The Elma loam is chiefly alluvial in origin, although mixed with some colluvial and glacial material. The alluvial and colluvial portions have been derived chiefly from the residual hills of Melbourne silty clay loam and usually rest upon a stratum of coarse glacial gravels from which the greater proportion of the fine material has been washed.

Seven bodies of Elma loam have been mapped in the area. Six of these are found along the Chehalis River Valley, in Chehalis County, and one in the vicinity of Rochester, in Thurston County. The largest body lies west of Elma and embraces approximately 3 square miles. Another body, about 1 square mile in extent, occurs 2 miles east of Montesano. The remaining areas are considerably smaller, ranging in size from a few acres to a quarter section.

The type has a comparatively level topography, with sufficient slope from the uplands toward the valley to insure good surface drainage, while the porous character of the lower subsoil insures good underdrainage. There are a few small depressions that would undoubtedly be benefited by artificial drainage.

The original forest covering consists of fir, spruce, cedar, and hemlock, with a dense undergrowth of salal. Along the stream channels and in the depressions willows and alders are quite numerous.

Some tracts of the Elma loam are still timbered, but a large part of the area has been logged, and much of it west of Elma is being cultivated. The type seems well adapted to all the crops grown in the region. Oats, hay, and clover do well on all the soil, while on the better-drained areas such fruits as apples, pears, plums, strawberries, and raspberries are successfully grown. The principal crops grown are oats, wheat, and clover. Oats yield from 50 to 100 bushels per acre, wheat 25 to 50 bushels per acre, and hay 2 to 3 tons per acre. Potatoes are also grown to a limited extent, the yield ranging from 150 to 300 bushels per acre, depending on season and cultivation.

Well-improved farms of this type are held at \$150 to \$250 an acre, but the undeveloped cut-over tracts can be purchased for \$15 to \$75 an acre.

Mechanical analyses of samples of the soil and subsoil gave the following results:

Mechanical analyses of Elma loam.

Number.	Description.	Fine	Coarse	Medium	Fine	Very fine	Silt.	Clay.
		gravel.	sand.	sand.	sand.	sand.	Per cent.	Per cent.
25215.....	Soil.....	0.0	1.6	3.5	28.5	11.0	35.7	19.7
25216.....	Subsoil.....	.1	1.6	3.7	28.4	9.2	37.1	19.3

MARINE BEACH DEPOSITS.

MISCELLANEOUS TYPE.

COASTAL BEACH.

Coastal beach consists of the gray or white sands washed up and deposited along the shores of the ocean and the sound. The material consists of all the various grades of sand, and, having very little fine material and no organic matter, is loose and easily shifted by the winds.

The type occurs as long, narrow spits leading out into the Strait of Juan de Fuca at Port Angeles, Port Townsend, and Dungeness, and also as a narrow strip separating Grays Harbor from the ocean.

The greater part of the type is above the high-water mark, though during extremely high tide portions of it are inundated. It has no agricultural value.

EOLIAN DEPOSITS.

MISCELLANEOUS TYPES.

DUNESAND.

A more or less extensive area of Dunesand occurs in the southwestern part of the area surveyed, which is occupied by low mounds and ridges of drifting sands. The sand was first deposited along the coast line of the Pacific Ocean by the action of the waves and was later carried inland and drifted into mounds by the winds. The area occupied by these sand dunes is of limited extent, and the land is of no agricultural value.

WESTPORT FINE SAND.

The Westport fine sand consists of a gray or mottled gray and brown fine sand several feet in depth of so loose and incoherent a nature that it is easily moved by the winds unless protected by vegetation. The first 2 or 3 inches of the surface contain a small percentage of organic matter, which gives it a darker color and a more loamy texture than the underlying soil. In the more level areas and the depressions the proportion of fine material and organic matter is usually perceptibly greater, giving the soil in these localities a heavier texture than is characteristic of the type. Because of the loose structure of the surface material the soil is easily cultivated under a wide range of moisture conditions.

The Westport fine sand is of marine and Eolian origin, having been thrown up by the waves and then drifted into dunes by the winds.

All the type mapped is found in Chehalis County, where it occurs on the sheltered side of the sand spits which separate Grays Harbor from the ocean. These bodies extend as almost continuous strips from one-eighth mile to $1\frac{1}{2}$ miles wide across the western side of the county.

Some portions of the type are comparatively level or gently rolling, but as a rule the topography is marked by a series of long, narrow ridges from 10 to 40 feet high, between which hollows have been formed very little above sea level.

The native vegetation on the ridges consists of a stunted growth of fir and a dense undergrowth of salal, while in the hollows willows, alder, and small cedars abound.

The more level areas and depressions could be utilized to a limited extent in growing truck crops, small grains, and hay, but as a whole the type is unsuited to agricultural purposes. Only a small percentage of it is under cultivation, the crops grown being oats, wheat, hay, and

a little truck. Under the methods now being used the yields of all these crops are comparatively light. On cut-over areas and where the timber growth is not too dense the soil is used to some extent as a range for stock and during the greater portion of the year furnishes a fair amount of grazing.

ORGANIC ACCUMULATIONS.

MISCELLANEOUS TYPE.

MUCK AND PEAT.

Areas of Muck and Peat occur in almost every part of the glaciated portion of the survey. They represent deep accumulations of organic matter in various stages of decomposition, the greater proportion of which has become mixed with silt and clay forming the typical muck soil. In other areas the material is more fibrous and has more the characteristics of Peat than Muck. These two stages are so closely related and grade into each other so frequently within small areas that no attempt was made to separate them in the general classification of the soils.

Muck and Peat deposits occupy low, poorly drained basins, and are formed by the decay of rank, water-loving vegetation under conditions of poor drainage. When these deposits have a fibrous, peaty texture they are very difficult to cultivate, and are used mainly for pasture. Very little of the type has been cleared and put in cultivation, though valuable fields are found near Sequim, Shelton, and in the vicinity of Chimacum.

The greatest acreage of the type is devoted to pasturage. Hay and small grains are produced to some extent, and except in the driest seasons good yields are secured. Celery and cabbage are also produced to a limited extent, and under proper conditions of moisture make profitable crops. Because of the difference in improvements, market facilities, and drainage conditions the type has a wide range in agricultural value.

In the vicinity of Chimacum and Shelton the land is held at from \$50 to \$150 an acre, but unimproved land in more remote sections could probably be secured for \$10 to \$25 an acre.

CHEMICAL ANALYSES OF SOILS.¹

For the purpose of obtaining information regarding the composition of the various types of soil, samples were sent to the laboratory at the University of Washington for chemical analyses. Special care was exercised to have the samples represent the average conditions of the types from which they were selected. In nearly every

¹ By H. K. Benson, of the Washington Geological Survey.

case the samples were taken from logged-off or cut-over land, which had never been cultivated and had produced nothing except its first crop of timber. The samples were taken by means of a soil auger to a depth of 10 to 14 inches, or else obtained from sectional cuts to the same depth.

The mineral elements in the soil of the most interest to the agriculturist are calcium, potassium, phosphorus, and nitrogen. More commonly these chemical elements are spoken of as lime (calcium oxide), potash (potassium oxide), phosphoric acid (phosphorus pentoxide), and nitrogen. The latter is sometimes spoken of as ammonia, although undoubtedly present in the soil in other forms of a more complex nature. These constituents of the soil are sometimes called the main elements of fertility, for while other mineral elements are needed by growing plants, they are always abundantly present in the soil, while one or more of the mineral constituents mentioned are frequently present in a very minute quantity. In such cases it is sought to add them to the soil by the use of commercial fertilizers.

In addition to the analysis of a soil for the above constituents, some light on the condition of the soil may be obtained by determining its lime requirements. While this is expressed in percentage, it is based upon the number of pounds of limestone necessary to neutralize the acids of the soil. Thus in a soil where the lime requirement is expressed by 0.025 per cent it is understood that 0.025 pound of limestone is required to render 100 pounds of soil neutral or free from acid. These acids are supposed to be produced by the action of growing plants and to result from the breaking down of the organic matter in the soil. Lime being an alkaline substance will combine with such acids to form lime salts. Aside from its action on acids, lime exerts other and more complex influences. It induces a much better flocculation or crumbling of the soil, improving its tilth, aeration, etc., conditions very favorable for the growth of desirable kinds of bacteria in the soil, especially those kinds which gather nitrogen from the air and grow in symbiosis or association with leguminous crops, such as alfalfa, clover, and vetch. It is possible that lime may have a specific effect upon certain plants, and it is held by many fruit growers that an ample quantity of lime will cause the production of sweeter fruit.

The specific effects of the other mineral constituents of the soil are commonly stated in a general way, although other functions are doubtless performed. Potash is held to be of special importance in the production of starch in growing plants, and is needed in considerable quantities by fruits and vegetables. Phosphoric acid is regarded as mainly important in building up the protein matter in plants, and is therefore needed for seed production and required by

all crops, especially cereals. Nitrogen, as used by plants, is believed to be taken from the soil in the form of nitrates, and is elaborated or made over in the plant into various substances to form the green growing parts of the plant. No substance in the soil produces a more rapid or decided response in the crop than does nitrogen. A ready supply of nitrates is of the utmost importance to green crops, especially during the periods of most rapid growth, and it is desirable to have nitrogenous organic substances in the soil to furnish nitrates through their decay and oxidation.

The methods employed in the analyses of the soils are those of the Association of Official Agricultural Chemists. The analytical work was done by Mr. F. W. Ashton, assistant chemist, under the supervision of the writer. The soil samples were pestled and sifted through a 1 mm. sieve, the fine earth only being used in the analysis. To obtain an approximate idea of the organic matter present in the soil, the loss on ignition of a 1-gram sample of each soil was determined and the loss in weight expressed in per cent. This determination is open to objection, as in the case of some soils the loss represents mainly the removal of water from clay and water-holding minerals, but in the main the determination affords a means for judging the organic content of the soil. It is a matter of general experience, verified by analyses of soils in this region, that where the lime content of the soil is high much of the organic matter is present in a partially decomposed state, known as humus, and this view is supported by the following table:

Type.	Lime.	Phos- phoric acid.	Potash.	Loss on ignition.	Humus.	Lime require- ment.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sand.....	0.08	0.10	0.10	2.51	0.25	0.0214
Sandy loam.....	.54	.24	.52	7.96	3.68	.0114

The presence of a good supply of humus in the soil is of importance in promoting a proper aggregation or clustering of the soil grains, in favoring good tilth, and in benefiting the soil by increasing its capacity to hold water and retain from leaching the dissolved mineral plant nutrients.

The results of the analyses of the various soil types are given in the table on pages 109 to 111, which is for the most part self-explanatory. For convenience the quantity of limestone per acre necessary to give an alkaline reaction has been computed in the last column. Other analyses of soils from the area are to be found in Bulletins Nos. 13, 55, and 85, State College Experiment Station, Pullman, Wash., and in the report upon the Soil Survey of the Eastern Part of the Puget Sound Basin, Washington, United States Bureau of Soils, 1909.

Analyses of the various soil types of the western part of the Puget Sound

Lab- oratory No.	County.	Soil type.	Location.	Per cent.	
				Line.	Phos- phoric acid.
77	Kitsap	Everett gravelly loam	Sec. 34, T. 26, R. 1 E.	0.46	0.08
30	do.	do	N. 1/2 sec. 34, T. 25, R. 1 E.	.19	
29	Thurston	do	NE. 1/4 NW. 1/4 sec. 30, T. 16, R. 1 W.	.57	.11
31	Jefferson	do	NE. 1/4 sec. 10, T. 29, R. 1 W.	.28	.17
34	do.	do	SE. 1/4 sec. 28, T. 30, R. 1 W.	.90	.04
32	Kitsap	Everett gravelly loamy sand	NE. 1/4 sec. 11, T. 24, R. 1 E.	.85	.46
33	Chehalis	do	NE. 1/4 NE. 1/4 sec. 10, T. 17, R. 6 W.	.50	.41
33	Kitsap	Everett loamy sand	NE. 1/4 sec. 34, T. 25, R. 1 E.	.98	.47
36	Jefferson	do	NE. 1/4 sec. 16, T. 30, R. 1 W.	1.26	.24
37	do.	do	SW. 1/4 sec. 5, T. 30, R. 1 W.	1.07	.15
38	do.	do	SW. 1/4 sec. 16, T. 30, R. 1 W.	.94	.34
65	Thurston	do	Sec. 1, T. 16, R. 3 W.	.58	.31
66	do.	do	NW. 1/4 sec. 25, T. 18, R. 1 W.	.78	.26
75	Kitsap	do	Sec. 14, T. 24, R. 1 E.	.83	.14
92	Island	do	Sec. 34, T. 30, R. 3 E.	.11	.02
28	Clallam	do	NE. 1/4 sec. 25, T. 30, R. 4 W.	1.13	.48
51	Thurston	Spanaway gravelly sandy loam	SW. 1/4 NW. 1/4 sec. 30, T. 16, R. 1 W.	.56	.24
62	Chehalis	do	NW. 1/4 NW. 1/4 sec. 2, T. 17, R. 1 W.	.51	.33
53	do.	do	NW. 1/4 sec. 31, T. 16, R. 4 W.	.57	.20
57	Thurston	do	SE. 1/4 sec. 18, T. 30, R. 3 W.	.68	.30
58	do.	do	Sec. 13, T. 17, R. 2 E.	.59	.24
62	do.	do	SE. 1/4 sec. 26, T. 17, R. 2 E.	.86	.24
55	do.	Spanaway loamy sand	Sec. 4, T. 18, R. 1 W.	.76	.13
60	do.	do	NW. 1/4 sec. 4, T. 15, R. 3 W.	.73	.10
61	do.	do	Sec. 5, T. 17, R. 1 E.	.65	.12
56	do.	Spanaway loamy fine sand	Sec. 31, T. 18, R. 1 W.	.78	.14
59	do.	do	NE. 1/4 sec. 5, T. 17, R. 1 W.	.62	.16

Analyses of the various soil types of the western part of the Puget Sound Basin

Laboratory No.	County.	Soil type.	Location.	Lime.	Phosphoric acid.	Per cent.
49	Clallam.	Sequim gravelly sandy loam.	NE. 1 sec. 19, T. 30, R. 3 W.	1.09	.22	
50	do.	do.	SE. 1 sec. 18, T. 30, R. 3 W.	1.16	.28	
41	Thurston.	Everett fine sandy loam.	Sec. 18, T. 18, R. 1 W.	.85	.32	
42	do.	do.	Sec. 35, T. 18, R. 2 W.	.56	.70	
43	Jefferson.	do.	SW. 1 sec. 13, T. 28, R. 2 W.	1.24	.29	
44	Clallam.	do.	SW. 1 sec. 24, T. 30, R. 6 W.	.90	.18	
45	Jefferson.	do.	SW. 1 sec. 21, T. 28, R. 1 W.	1.10	.05	
46	do.	do.	NE. 1 sec. 9, T. 30, R. 1 W.	1.26	.05	
47	do.	do.	NE. 1 sec. 30, T. 30, R. 1 W.	1.17	.08	
39	Thurston.	Everett silt loam.	SW. 1 sec. 5, T. 19, R. 2 W.	1.01	.15	
40	do.	do.	500 yards from No. 39.	.94	.10	
63	do.	do.	SW. 1 sec. 24, T. 19, R. 2 W.	.80	.08	
64	do.	do.	NW. 1 sec. 14, T. 19, R. 2 W.	.69	.06	
71	Island.	Everett sandy loam.	NW. 1 sec. 29, T. 31, R. 2 E.	.74	.21	
72	do.	do.	Sec. 11, T. 31, R. 1 E.	.82	.26	
91	do.	Clallam silt loam.	Sec. 10, T. 31, R. 1 E.	.58	.19	
93	do.	Bellingham silt loam.	Sec. 34, T. 38, R. 1 E.	.19	.14	
94	do.	Peat.	Sec. 17, T. 32, R. 1 E.	.15	.18	
95	do.	Bellingham silt loam.	Sec. 34, T. 38, R. 1 E.	.13	.17	
96	do.	Ebey's sandy loam.	Sec. 4, T. 31, R. 1 E.	.51	.15	
73	do.	do.	Sec. 12, T. 31, R. 1 E.	.98	.22	
74	do.	do.	SE. 1 sec. 5, T. 31, R. 1 E.	.62	.17	
97	do.	do.	Sec. 30, T. 32, R. 1 E.	.54	.24	
4	Clallam.	Olympic loams.	NE. 1 sec. 4, T. 31, R. 12 W.	.29	.25	
22	do.	do.	SW. 1 sec. 14, T. 31, R. 12 W.	.26	.33	
23	Thurston.	do.	NE. 1 sec. 19, T. 19, R. 2 W.	1.30	.33	
24	Jefferson.	do.	SE. 1 sec. 17, T. 29, R. 1 W.	.38	.25	

1	Clallam	Bellingham silt loam	1.39	.21
2	Jefferson	do	.59	.10
3	Clallam	do	.16	.16
5	Chehalis	Hoquiam clay loam	1.37	.137
13	do	do	SE. $\frac{1}{4}$ sec. 27, T. 31, R. 8 W.	1.37
6	do	Montesano clay loam	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 26, T. 20, R. 12 W.	.14
7	do	Melbourne silty clay loam	SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 1, T. 19, R. 10 W.	.03
8	do	do	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 1, T. 19, R. 12 W.	.08
9	Thurston	do	SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 27, T. 18, R. 6 W.	.46
10	do	do	NE. $\frac{1}{4}$ sec. 24, T. 17, R. 8 W.	.46
14	Chehalis	do	NE. $\frac{1}{4}$ sec. 30, T. 16, R. 1 W.	.17
70	do	do	SW. $\frac{1}{4}$ sec. 28, T. 18, R. 5 W.	.20
11	do	do	SW. $\frac{1}{4}$ sec. 33, T. 33, R. 9 W.	.14
26	do	do	SW. $\frac{1}{4}$ sec. 6, T. 15, R. 4 W.	.74
27	do	do	SW. $\frac{1}{4}$ sec. 27, T. 20, R. 10 W.	.18
12	do	do	SW. $\frac{1}{4}$ sec. 5, T. 17, R. 7 W.	.27
15	do	Westport fine sand	NE. $\frac{1}{4}$ sec. 12, T. 17, R. 8 W.	.45
17	do	do	NW. $\frac{1}{4}$ sec. 27, T. 19, R. 12 W.	.76
16	do	do	SW. $\frac{1}{4}$ sec. 8, T. 20, R. 12 W.	.05
18	do	do	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 2, T. 20, R. 10 W.	.05
19	do	do	SE. $\frac{1}{4}$ sec. 4, T. 17, R. 10 W.	.70
20	do	do	Lot 2, sec. 4, T. 17, R. 10 W.	.18
67	do	do	SE. $\frac{1}{4}$ sec. 6, T. 15, R. 4 W.	.49
68	do	do	SW. $\frac{1}{4}$ sec. 6, T. 17, R. 6 W.	.14
21	do	do	SW. $\frac{1}{4}$ sec. 2, T. 17, R. 6 W.	.01
25	Thurston	Copalis clay loam	NW. $\frac{1}{4}$ sec. 6, T. 15, R. 4 W.	.04
48	Clallam	Eld silty clay loam	SE. $\frac{1}{4}$ sec. 23, T. 19, R. 11 W.	.16
69	Chehalis	Dungeness silt loam	NE. $\frac{1}{4}$ sec. 25, T. 19, R. 3 W.	.23
		Melbourne silty clay loam	NW. $\frac{1}{4}$ sec. 11, T. 30, R. 4 W.	.03
			SE. $\frac{1}{4}$ sec. 25, T. 17, R. 8 W.	.11
				.24
				.25

These analyses show that the soils of the area compare well with the general run of soils in good agricultural areas of similar rainfall and other climatic conditions. The effect of the latter is strikingly evident by a comparison of certain types of soil in the more humid section with similar soils in portions of Clallam and Jefferson Counties, where the rainfall is much below the average. On account of such cases and other conditions not easily explained, it will be observed that the variations in the figures for any one type of soil are about the same as the variations between types. Consequently, so far as these analytical data show, the chemical composition of the soil is not a type characteristic. That is to say, the main differences in the soils of this area are in their physical and perhaps biological characteristics and the chemical differences, outside of the uniform exception above noted, are of importance only in the individual fields, but not between types.

The interpretation of a chemical analysis of a soil is a matter of extreme difficulty. As stated above, these analyses show the soils of the area to be similar in composition as regards the content of lime, potash, and phosphoric acid to good soils of similar areas elsewhere. As a matter of general experience, some authorities, notably Hilgard¹ and Maercker,² have suggested arbitrary standards as to the quantities of the different constituents which soils of different textures should have. By these standards the above analyses show the soils of the area to be generally quite satisfactory. But it is impossible to apply such standards in any rigid manner, and it is quite possible for the inexperienced layman or farmer without the necessary technical training to draw quite erroneous conclusions. Therefore it has not been considered necessary or desirable to tabulate a direct comparison for this report, but to make the simple statement that the data given here, whether by comparison with data for other localities having similar climatic conditions or by other standard methods, show a generally satisfactory state of affairs as regards the chemical composition of the soils of the area.

¹ Soils, E. W. Hilgard, p. 377. The average of the analysis of 696 samples of virgin soil taken from the humid region is here stated as follows: Lime, 0.13 per cent; phosphoric acid, 0.12; potash, 0.21; loss on ignition, 4.40.

² An arbitrary standard for the rating of soils by plant-food percentages was formulated for European soils by Prof. Maercker, of the Halle Station, Germany. While these ratings have failed of general acceptance, even by the soil chemists of Germany, they are here given for the purpose of indicating an approximation of the quantities of plant-food percentages in soils of various grades:

	Potash.	Phosphoric acid.	Lime in sandy soil.	Nitrogen.
Poor soil.....	Per cent. Below 0.05	Per cent. Below 0.05	Per cent. Below 0.05	Per cent. Below 0.05
Normal soil.....	0.15-0.25	0.10-0.15	0.15-0.20	0.10-0.15
Rich soil.....	Above 0.40	Above 0.25	Above 0.30	Above 0.25

On the other hand, while the data show that the soils of this area are not deficient in essential mineral constituents, they do not show any unusually large percentages of these constituents, and there is every reason to believe that the three important methods of soil control which have proved successful on similar soils under similar conditions elsewhere would prove effective in this area. Deep and thorough tillage, while improving the general physical, chemical, and biological conditions in these soils, is especially important for improving the aeration and counteracting the tendency toward sourness. To this end, also, it appears wise to lime these lands frequently. An application of 40 to 50 bushels of air-slaked lime or finely ground limestone per acre every few years, or perhaps once in every second rotation, will probably prove very effective, and more so if a crop rotation is used in which grass or a clover or other like legume enters at intervals of three or four years. It is clearly desirable to have these soils at frequent intervals under a crop which does not require clean cultivation.

Finally, the third method of control—the use of fertilizers—would probably be found efficacious in the area. Besides as liberal a use as possible of stable manures and green manures, high-grade fertilizers should be used. The local differences for each field and crop make it hazardous to give general advice in this connection, and it will be wiser for the individual farmer to consult the authorities of the State experiment station for specific advice and assistance.

CONCLUSIONS FROM CHEMICAL ANALYSES.

(1) Chemical analyses of representative samples of various soil types of the area show large variation within the type, but in the main the soils of the area are above the average in content of important mineral plant nutrients as compared with soils in other areas under similar climatic conditions.

(2) Specific rather than general consideration should be given to the enrichment of the soil in certain localities. For instance, the lime content of two soils in Chehalis County varies from 1.44 per cent to 0.03 per cent.

(3) Analytical results indicate that many of the soils would respond well to liming.

SUMMARY.

The area surveyed includes San Juan, Island, Thurston, and Kitsap Counties and parts of Chehalis, Jefferson, Clallam, Mason, and Pierce.

Two maps have been made of the entire area; a general soil map showing the character of the soil embraced by the survey, and a land classification map showing the areas of logged-off, timbered, and

cultivated lands, in eight general divisions according to its agricultural value.

A large proportion of the area consists of rolling uplands and broad alluvial river valleys. In some localities, such as the sections which include the foothills of the Olympic Mountains, the topography is rough and broken. A large proportion of San Juan County is hilly with large areas of rock outcrop. With the exception of the small areas of Tidal marsh, which occurs at the outlet of the larger rivers, the land of the entire area is generally well drained. On some of the glacial uplands its natural drainage is excessive.

The alluvial valleys are comparatively thickly settled, but much of the rolling upland section is sparsely populated, while the rough and mountainous sections are almost uninhabited.

The southern part of the area is traversed by the trunk line and branches of several transcontinental railroads. The islands and area bordering Puget Sound are served by the small steam packets plying between the larger cities and the smaller ports along the Sound. Every part of the area is within easy reach of one of the larger local markets. Seattle, Tacoma, and Portland are the principal market centers of the area. Lumbering is still the principal industry over a large proportion of the area surveyed.

Agriculture has progressed rapidly in the alluvial valleys. On the uplands the cost of clearing the logged-off lands has somewhat retarded development.

Dairy farming is one of the most profitable industries of the area, and in certain sections fruit growing is rapidly assuming large proportions. In the southern portion and along the alluvial valleys oats and other small grains are extensively grown.

The cultivated areas in the glacial uplands are utilized mainly for such crops as will yield large returns from the intensive cultivation of a small acreage. Irish potatoes, strawberries, and other small fruits when properly cultivated do well on these soils. The small orchards of apples, pears, plums, prunes, and similar fruits produce large yields. Only a limited acreage of the uplands occupied by the residual soils is under cultivation, but the soils are productive and when properly cultivated produce large yields of all crops grown. Hops are grown to a limited extent in the alluvial valleys with universally large yields.

Oats, hay, and potatoes are the staple products of the area. The hay and grain crops are grown mainly on the alluvial soils and on the level bench lands occupied by the residual soils. Canada field peas do well on almost every type of soil suitable for agriculture.

Forty-seven types of soil occur in the area. These have been separated broadly into 13 general groups. The first group includes the

glacial upland soils derived from both ice-laid and water-laid materials forming the glacial drift. This group includes soils of the Everett and Clallam series. The greater proportion of the soils of these series is excessively drained, but they produce profitable yields where intensive methods of cultivation are employed. The Whatcom silt loam, Townsend gravelly sandy loam, and San Juan coarse sandy loam also belong to this group.

The second group embraces the soils derived from material deposited as glacial outwash exclusively. In this group come the soils of the Spanaway series. The soils are of gravelly character and marked by excessive subsoil drainage. The coarser and more gravelly types are of little agricultural value.

The third group includes sedimentary deposits in shallow basins of glacial lakes or depressions and includes the Bellingham silt loam and the Ebey's sandy loam.

The fourth group includes soils derived from old sedimentary deposits. These soils are more or less silty. They form good farming land.

This group embraces the Hoquiam clay loam, Copalis clay loam, the Dallas coarse sandy loam, and the members of the Montesano series.

The fifth group comprises a residual soil derived directly from the weathering of the underlying rocks occurring in the hilly districts. The soil (the Melbourne silty clay loam) is usually of more or less silty texture. It is productive under cultivation, but much care is necessary to prevent erosion on the more rolling areas.

The sixth group embraces the soils of the rough mountainous regions. These soils are variable in texture and derived from both residual and glacial materials. The soils occupying small benches or level plateaus are comparatively free from stones and can be profitably used for agriculture, but the greater proportion of the mountain soils have such a steep and broken topography and contain such a large amount of stone in both the soil and subsoil that they are practically valueless for any purpose except forestry. No attempt has been made to separate the group into the various types represented, but the material has been mapped mainly under the name of the Olympic loams, although certain bodies of soil of this character are included within the Everett series.

The recent alluvial soils comprising the seventh group consist of stream flood plain deposits in stream valleys and form the most extensively developed and productive soils of the area surveyed. They embrace the soils of the Puget, Chehalis, and the Eld series.

The eighth group embraces only nonagricultural tidal estuarine deposits mapped as Tidal marsh.

The ninth group embraces soils derived from ancient alluvial deposits. It comprises the two members of the Dungeness series and one local type, the Sequim gravelly sandy loam. The Dungeness soils have a comparatively level topography, are well adapted to agriculture, and when well cultivated produce profitable yields of all crops grown. The Sequim gravelly sandy loam has a coarse, porous texture, but a large acreage of this type is at present under irrigation, producing large yields of oats, hay, and other general farm crops.

The tenth group consists of mingled material of glacial outwash, colluvial material, and alluvial stream deposits, constituting the Elma series.

The eleventh group comprises the beach deposits. These sandy and gravelly deposits are of limited extent and are of no agricultural value.

The twelfth group comprises the soils of Eolian origin. The areas of Dunesand included under this group are of no agricultural value, but small areas of the Westport fine sand are utilized for farming purposes.

The thirteenth group embraces deposits occupying the beds of former lakes or shallow, poorly drained basins, and formed of decomposing vegetable matter. This group includes the material mapped as Muck and Peat.



[PUBLIC RESOLUTION - No. 9.]

JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided*, That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the Congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]

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